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PRISM 26

SDG 15

PROCEEDINGS OF

National Conference on Innovation and Resilience Strategies in Plant Protection (PRISM 26)

OCTOBER 22 & 23, 2026





Organized by

Department of Entomology & Department of Plant Pathology

SRM College of Agricultural Sciences, SRM Institute of Science and Technology

Baburayanpettai, Chengalpattu Dist. - 603 201

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Proceedings of

NATIONAL CONFERENCE ON INNOVATION AND RESILIENCE STRATEGIES IN PLANT PROTECTION (PRISM 26)

(*SDG 15 - Life on Land*)

22nd and 23rd OCTOBER 2026

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Dr. **M. JAWAHARLAL**, Ph.D.,
Dean

Date: 15.10.2026



MESSAGE FROM THE DEAN

It gives me immense pleasure to convey my best wishes for the successful conduct of the **National Conference on Innovations and Resilience Strategies in Plant Protection (PRISM 26)**, organized by the Department of Entomology and Department of Plant Pathology, SRM College of Agricultural Sciences, SRM Institute of Science and Technology, on October 22–23, 2026.

The theme of the conference, **"Plant Protection: Resilience, Innovation, Sustainability and Management,"** is highly relevant in the present agricultural scenario, where crop production faces increasing challenges from emerging pests and diseases, climate variability, changing agroecosystems, and the need to minimize environmental impacts. Ensuring sustainable crop health requires innovative scientific approaches, resilient crop protection strategies, and the effective integration of research, technology, and field level practices.

The conference provides a valuable platform for scientists, academicians, researchers, research scholars, and students to exchange knowledge, present their research findings, and deliberate on emerging developments in agricultural and biological sciences for sustainable crop protection. The emphasis on innovative approaches and resilience strategies will help strengthen interdisciplinary collaboration and encourage the development of environmentally sound, economically viable, and socially responsible plant protection practices.

I am confident that the scientific deliberations and research contributions presented through PRISM 26 will enrich the existing body of knowledge, inspire young researchers, and promote meaningful collaborations among institutions and stakeholders in agriculture. I also hope that the proceedings will serve as a useful reference for future research and contribute to advancing sustainable agriculture and food security.

I congratulate the organizing committees, contributing authors, invited speakers, and participants for their valuable efforts in bringing this academic initiative to fruition. I extend my sincere wishes for the grand success of PRISM 26 and hope that the conference will inspire innovative ideas and resilient solutions for the future of plant protection.

With best wishes,

Dr. M. Jawaharlal

Dean

SRM College of Agricultural Sciences
SRM Institute of Science and Technology (SRMIST)

NATIONAL CONFERENCE ON PRISM 26 (*SDG 15- LIFE ON LAND*)

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INNOVATIONS IN AGRICULTURAL AND BIOLOGICAL SCIENCES FOR SUSTAINABLE CROP PROTECTION

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Abstract

Sustainable crop protection is evolving through innovations in genetics, seeds and biological solutions. These technologies help agriculture boost resilience, reduce environmental impact and optimize productivity. Collaboration across research, industry and farming communities is key to adopting them effectively. Advances in genetics and seed technologies are transforming agriculture by boosting crop resilience to pests, diseases and environmental stresses, enabling nutrient use efficiency for higher yields with more sustainable crop protection production. 'Gene editing and enhanced seed traits, such as disease and herbicide resistance and climate stress tolerance, improve pest and weed management, support sustainable chemical use, promote efficient water use and improve soil health. These innovations also enable conservation practices like reduced tillage, preserving moisture and organic matter, preventing erosion and protecting biodiversity. Biopesticides and biofungicides are natural alternatives to traditional chemical pesticides. Biopesticides faces persistent challenges such as regulatory inconsistencies, limited farmer awareness, variable efficacy and supply chain constraints. Divergent regulations often require repetitive testing and lengthy approvals, delaying market entry. Sensitivity to environmental conditions can cause inconsistent performance, while many growers remain unfamiliar with their use in pest management. Supply, storage, and distribution issues further limit access, particularly in remote areas. Overcoming these barriers requires coordinated actions viz., harmonized, science-based regulations with standardized data packages, large-scale trials to build trust and validate efficacy, farmer training and extension services for integration into IPM and stronger supply chains with modern infrastructure. Digital advisory tools, such as region-specific farm guidance, can further support adoption by improving application timing and dosage.Despite challenges, biopesticides offer clear advantages. Their biodegradability, target specificity and ability to reduce pesticide resistance make them valuable for both horticulture and field crops. While their narrow pest focus can

complicate management, integration into IPM turns this specificity into an advantage by minimizing non-target impacts and supporting ecological balance.

Genetic advances stack resistance and tolerance traits that reduce pest and disease pressure, lower dependence on chemical inputs and help slow the development of resistance. Improved coatings and priming technologies strengthen emergence and early vigor, while breeding for enhanced root traits builds stronger relationships with beneficial microbes. Stress-tolerant varieties for heat, drought and salinity safeguard yields under increasingly variable climate conditions. Usage of humic acids, unlock soil nutrients and improve fertilizer efficiency, while seaweed extracts boost stress resilience and plant health. Together, these tools reduce emergency pesticide applications, cut costs and support stable yields. Rapid advances in genome editing, especially CRISPR, have enabled precise, faster crop improvements than traditional breeding. Coupled with AI-driven bioinformatics and availability of fast and economic genome sequencing, these tools unlock new genetic pathways for climate-resilient, resource-efficient, high-yielding crops. Integrating AI and biotechnology optimizes breeding, accelerates innovation, and combined with responsible farming, makes agriculture more efficient, sustainable, and environmentally friendly. Collaboration among researchers, policymakers and farmers will further accelerate adoption, helping agriculture adapt to climate challenges.'Clear communication on risk, safety and environmental impact builds trust with regulators and policymakers. Farmer adoption requires practical, field-tested solutions integrated into existing practices, supported by training, demonstrations and extension services. Market-driven sustainability programs and industry initiatives further encourage adoption by showing long-term value. Collaboration among agribusinesses, researchers and farmer organizations provides localized data and best practices for IPM integration, while digital platforms and real-time advisory services help farmers make informed decisions.

Keywords: Biopesticides, biofungicides, IPM integration, digital platforms

MILD STRAIN CROSS-PROTECTION AGAINST CITRUS TRISTEZA VIRUS: RESEARCH ADVANCES AND SUSTAINABLE MANAGEMENT OF CITRUS DECLINE IN INDIA

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Abstract

Citrus tristeza virus (CTV), a brown citrus aphid (BrCA) (*Toxoptera citricidus*) transmitted closterovirus, has destroyed millions of citrus trees worldwide, including India. The virus contains flexuous filamentous particles (2000 x 11 nm), +ve sense ssRNA (~19.3 kb with 12 ORFs encoding 19 proteins) genome. CTV is a century old problem and infects most of the citrus cultivated in all the geographical zones of India. Based on extensive survey, overall disease incidence is 26.3- 60% in India; where 47-56% in NE, 36.3% in Central, 36-50% in South and 16-60% in NW India. CTV has diversity of phenotypes: decline, stem pitting, seedling yellows, vein clearing, vein flecking and vein corking. CTV has exhibited a wide range of genetic diversity in the natural environment and existence of several genetically divergent CTV isolates have been reported from many citrus growing regions of India. Based on sequence analysis of more than 150 CTV isolates, existence of 10 distinct CTV variants in India are determined. The Codon usage biasness (CUB) analysis of the CP genes of about 122 CTV isolates originating from *C. sinensis* (Sweet orange*)*, *C. reticulata* (Mandarin), *C. aurantifolia* (Acid lime) showed that CTV displays low CUB and higher genomic stability resulting in higher adaptability of CTV isolates originating from mandarin, and low adaptability originating from acid lime and sweet orange and combination codon analysis suggests that CTV has originated from mandarin million.

Mandarin (*C. reticulata*), the most widely cultivated commercial citrus fruit plants in NE India and is tremendously affected by the decline caused by CTV that causes huge losses. No direct and effective management strategy and genetic resistance for citrus decline are available. Eradication of CTV by removing the infected citrus plant is not practical for management of this disease. Mandarin cultivation is now increasingly being abandoned or shifted to other crops, even newly established orchards are becoming affected. Thus, development and use of CTV-free/resistant/immune citrus planting materials are urgently. This requires the production of disease-free Khasi mandarin seedlings and grafted plantlets. For these purpose, identifications and maintenance of disease-free mother stocks as source of scions are foremost

needed. Mild strain cross-protection (MSCP) is a promising strategy for managing CTV decline and it is successfully practiced in many countries. It involves the prior infection of healthy plants with a mild strain to protect them against subsequent infection of severe strains. In NE India, mild and severe CTV infections have been identified based on sequence and CUB analysis of CTV genes, and followed by preliminary biological indexing. The identified mild CTV strains require detailed biological characterization and validation to confirm their potential as effective cross-protecting mild strain against severe CTV strains for effective management of citrus decline.Citrus decline in NE India is very old and occurs almost in all the citrus growing areas of this region with high disease incidence. Moreover, occurrence of BrCA is very much common, which efficiently transmits and spread CTV locally. Old and sick orchards are abandoned due to severe citrus decline. Newly established orchards are also affected by this disease very fast due to planting of infected planting materials and then locally spread by BrCA. Traditional management practices failed to protect citrus tree from CTV and also there is no good source of resistance. Therefore, it is high time to rejuvenate the mandarin industry in NE India through intervention by biotechnology-based tools undertaking a management strategy of development of transgenic resistance. For development of transgenic resistant citrus, several anti-sence (RNAi) and hairpin (ihp-RNAi) constructs targeting CP and Sup gene of CTV were made in pBinAR and pRNAi-GG. Agrobacterium-mediated transformation protocol with regeneration efficiency of was 1.38% was developed. Hoowever, Repeated failure to obtain durable transgenic resistance of citrus targeting numbers of CTV genes like CP, p20, and p23 genes inducing RNA silencing have been tested with low success; has left mild strain cross protection (MSCP) and cross-protection with appropriate mild strain as the only means to protect commercial citrus varieties from CTV. Development of pre-inoculated mild strain cross protected citrus materials will be protect the severe strain and further, cross protection will extend the economic life of field infected mandarin tree by inoculation of MSCP strain allowing time to re-plantation. MSCP of CTV was initiated during 1970s in South India, however, effort of MSCP experiment was failed and it might be due to probably arbitrary selection of mild stains which were not true and pure mild strain culture. In this respect, three putative CTV mild isolates, MB3, CRS4 and Mnp3 strains have been identified based on *in silico* codon usage biasness (CUB), nucleotide identity and phylogenetic analysis using CP gene of CTV and preliminary biological indexing, those are yet to be confirmed biologically as pure and effective mild strains.

Keywords: Citrus tristeza virus, brown citrus aphid**,** mild strain, cross protection.

MPACT OF CLIMATIC CHANGE ON PLANT DISEASES

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Abstract

Global climate change, characterized by rising temperatures, elevated CO_2 concentrations, unseasonal rainfall, humidity, retreating glaciers in the Himalayan region and unpredictable precipitation patterns, poses a huge threat to agricultural production, productivity and quality of food security in India. Global warming is projected to reach 1.5 °C above pre-industrial levels between 2030 and 2052 period, if the current greenhouse gas emission rate continues, according to the Intergovernmental Panel on Climate Change (IPCC). The globally averaged surface concentration of CO_2 (the primary driver of global warming) reached 420.0 ppm, methane (a powerful, fast-acting greenhouse gas) 1,934 ppb, and nitrous oxide (a major ozone-depleting chemical) 336.9 ppb in 2023, These values are 151%, 265%, and 125% of pre-industrial levels, respectively (WMO, 2024). Alterations in climatic factors directly and indirectly influencing the plant pathogen interactions, pathogen colonization, survival, dissemination and reproduction, often transforming minor diseases into major agricultural biological threats. For instance, increased atmospheric humidity and prolonged leaf wetness period, cooling climatic conditions exacerbate fungal outbreaks, while warmer climates expand the range of insect vectors transmitting viral plant pathogens. Dry root rot in Chickpea and Cotton, Bacterial blight, Sheath blight and False smut in rice, Twig blight or Die-back in fruit crops, Anthracnose in Chilli and Soybean, Spot blotch, Leaf rust in wheat, Asiatic canker in Citrus, *Geminiviruses* were historically considered minor or regionally confined in India have escalated into major agricultural threats. This shift is mainly driven by fluctuating climatic weather parameters (elevated temperatures, erratic rainfall, moisture stress) combined with intensive cultivation practices like high planting densities and mono-cropping. Consequently, India faces a projected crop production loss of 10–40% by the end of the century due to global warming-induced stresses. The shifting dynamics of plant diseases also challenge the efficacy of existing chemical management and traditional disease management practices. Therefore, an urgent need for adaptive strategies, including the development of climate-resilient crop varieties, the implementation of advanced weather-based disease forecasting models, decision

supporting systems and the adoption of Integrated Plant Health Management practices tailored to India's varied climatic zones to safeguard agricultural sustainability.

Keywords: Climate change, Plant pathogens, Host-pathogen interaction, Elevated CO_2.

PLANT DERIVED BIOACTIVE PROTEINS AND PEPTIDES: EMERGING PERSPECTIVES IN PLANT PATHOLOGY AND DISEASE MANAGEMENT

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Abstract

Plant diseases caused by fungi, bacteria, oomycetes, viruses, and nematodes pose significant challenges to agricultural productivity and food security. Understanding the molecular interactions between plants and pathogens is essential for developing sustainable strategies for disease management. Plants possess sophisticated defense mechanisms involving pathogen recognition, immune signaling, antimicrobial compounds, and pathogenesis-related (PR) proteins. Among these defense components, bioactive proteins and peptides, particularly protease inhibitors, have attracted considerable interest because of their potential roles in plant defense and agricultural biotechnology.

The mechanisms underlying plant–pathogen interactions, including pattern-triggered immunity, effector-triggered immunity, reactive oxygen species production, hypersensitive responses, and systemic acquired resistance. Particular emphasis is placed on plant-derived protease inhibitors, their classification, biological functions, and potential applications in managing plant pathogens and associated pests. The purification and characterization of bioactive protein inhibitors from medicinal and agricultural plants, including *Tinospora cordifolia*, *Eleusine coracana*, *Leucas aspera*, and *Cheilocostus speciosus*, are discussed. Techniques such as chromatographic separation, electrophoretic analysis, enzyme inhibition assays, and mass spectrometry provide valuable approaches for identifying and characterizing these molecules. The potential multifunctional activities of selected plant proteins and peptides, including enzyme inhibition and anti-quorum-sensing effects, further expand their relevance in biotechnology. Overall, plant-derived bioactive proteins and peptides represent promising resources for understanding plant defense and developing environmentally compatible crop protection strategies.

Integrating biochemical characterization with molecular and functional studies may facilitate the discovery of novel bioactive molecules and support future applications in sustainable agriculture, plant pathology, and biotechnological innovation.

Keywords: Plant Pathology; Protease Inhibitors; Plant Defense Mechanisms; Bioactive Proteins and Peptides; Plant–Pathogen Interactions.

INNOVATIVE INSECT BEHAVIOURAL APPROACHES FOR PLANT PROTECTION

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Abstract

The 21st century is a time of great challenges for global agriculture, with the world population expected to reach about 10 billion by 2050 . This demographic shift requires a significant increase in crop productivity; however, at the same time, there is growing pressure to reduce the use of conventional chemical pesticides due to environmental and health concerns. Consumers are increasingly demanding safe, healthy food with minimal chemical residues, driving the need for sustainable agricultural practices. Innovative solutions are required to address these complex challenges to enhance crop yield and quality while managing pest resistance and minimizing environmental impact. In this context, semiochemicals have emerged as a promising alternative to conventional pesticides, offering a more targeted and environmentally friendly approach to pest management. Semiochemicals are chemicals that mediate interactions between organisms. The past 100 years have seen dramatic philosophical shifts in our approach to controlling or managing pest species. The introduction of integrated pest management in the 1970s incorporated biological and behavioural approaches to preserve ecosystems and reduce reliance on synthetic chemical pesticides. Increased understanding of the local ecosystem, including its structure and the biology of its species, can improve efficacy of integrated pest management strategies. Pest management strategies incorporating insect learning paradigms to control insect pests or to use insects to control other pests can mediate risk to nontarget insects, including pollinators. Although our understanding of insect learning is in its early stages, efforts to integrate insect learning into pest management strategies have been promising. Due to considerable differences in cognitive abilities among insect species, a case-by-case assessment is needed for each potential application of insect learning within a pest management strategy. Behavior manipulation is becoming an accepted tactic in pest management, however, there are many ways in which the approach can be improved. This review explains how and why insect behavioural responses to various stimuli can vary dramatically under different conditions, and why understanding this variability is essential before behaviour manipulation becomes widely accepted in pest management programs. This

review provides examples from a range of behavior manipulation tactics, including use of attracticides, kairomone-mediated biological control, use of marking pheromones, and push-pull manipulation. The simulation framework is a valuable tool to test hypotheses on insect behaviour and dynamics in heterogeneous environments and can be used to determine optimal diversification systems and hence generate guidance for establishing environmentally benign pest control strategies. In recent years, semiochemical-based pest management strategies have gained significant attention as they offer sustainable alternatives to conventional pesticides. Integrating semiochemicals into pest management strategies presents innovative approaches to addressing agricultural challenges. One promising method involves combining pheromones with entomopathogenic fungi, utilizing a " lure and infect" technique that attracts pests to fungal pathogens, enhancing control efficacy. Another advancement is the auto-dissemination approach, which promotes the spread of microbial pathogens within insect populations, effectively targeting pests like the fall armyworm. Research into the production of insect pheromones in plants further supports sustainable pest management by disrupting pest mating behaviors. Electroantennography has emerged as a valuable tool for understanding insect olfaction, aiding in the identification of effective semiochemicals. The push-pull strategy employs plant semiochemicals to manipulate pest behavior, while pheromone dispensers provide efficient and long-lasting applications of these compounds. Collectively, these advancements highlight the potential of semiochemicals in revolutionizing pest management practices, aligning with the increasing demand for sustainable agricultural solutions. Continued research and innovation in these areas are crucial for optimizing the use of semiochemicals, ultimately contributing to more effective and environmentally friendly pest control methods. However, there is still a huge, unrealised potential in the use of this insect-specific ecological information to elucidate insect community and population dynamics in open heterogeneous field systems.

Keywords: Semiochemicals; electroantennography; push-pull strategy; Behavior manipulation; trapping techniques

CLIMATE RESILIENT INTEGRATED PEST MANAGEMENT: EMERGING APPROACHES FOR SUSTAINABLE CROP PROTECTION UNDER A CHANGING CLIMATE

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Abstract

Climate change is emerging as a major challenge to agricultural productivity and food security, with significant implications for the distribution, abundance, development and damage potential of insect pests. Rising temperatures, altered precipitation patterns, elevated atmospheric carbon dioxide and extreme weather events are influencing insect host plant interactions, pest population dynamics and the effectiveness of existing crop protection strategies. These changes may favour the expansion of pest species into new geographical regions, increase outbreak frequency and modify the seasonal occurrence of important agricultural pests. Consequently, conventional pest management approaches based primarily on calendar driven pesticide applications may become less effective and environmentally sustainable. Climate resilient integrated pest management (IPM) offers an adaptive framework for mitigating climate associated pest risks while maintaining crop productivity and ecological stability. Weather-based pest forecasting, geographical information systems, remote sensing, artificial intelligence and decision-support tools can strengthen early detection and facilitate timely interventions. Conservation and augmentation of biological control agents are important components of resilient IPM; however, their performance under changing climatic conditions depends on thermal tolerance, ecological adaptability and interactions with host pests and crop environments. Climate smart cultural practices, such as crop diversification, intercropping, adjusted sowing dates, resistant cultivars, habitat manipulation and conservation of beneficial organisms, can further reduce pest vulnerability. Judicious pesticide use, resistance management and the integration of biopesticides with other control measures are also essential for sustained pest suppression. Developing effective climate resilient IPM requires multidisciplinary collaboration among entomologists, climatologists, agronomists, plant breeders and farmers. Strengthening climate-informed surveillance, refining location-specific forecasting models and validating adaptive strategies under field conditions remain important research priorities. Climate resilient IPM represents a proactive and sustainable approach to emerging pest challenges under a changing climate. Its implementation can enhance

agricultural resilience, conserve biodiversity, reduce pesticide dependence and support sustainable crop protection. Farmer participation, institutional collaboration and climate-informed decision-making will be crucial to translate these approaches into effective field-level practices.

Keywords: Climate change; Climate-resilient agriculture; Integrated pest management; Biological control; Pest forecasting; Sustainable crop protection

EVALUATION OF BIO-EFFICACY AND PHYTOTOXICITY OF FLINT PRO 64.8 WG (TRIFLOXYSTROBIN 3.5% + PROPINEB 61.3 % WG) AGAINST BROWN LEAF SPOT AND NARROW LEAF SPOT OF RICE

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Abstract

India's estimated rice production for 2024-25 reached a record high, with the Kharif season production estimated at 119.93 million tonnes and overall production for the year projected to be around 135.7 million tonnes (combining Kharif and Rabi estimates). This increase was driven by favourable monsoon rains, which boosted yield growth from previous years. The national average yield is projected to have increased from 2717 kg/ha in 2020-21 to 2899 kg/ha in 2024-25. Many species of the genus *Bipolaris* infect a wide range of crops around the world. *Bipolaris* fungi causing brown lesions, such as spot blotch of wheat (caused by *Bipolaris sorokiniana*), southern corn leaf blight of maize (caused by *B. maydis*) and brown spot (BS) of rice (caused by *B. oryzae*) have strong socio- economic impacts due to the importance of these crops in human and animal food chains. Brown Spot of rice can occur at any plant phenological stage. It can reduce grain germination, increase seedling mortality and limit the photosynthetic leaf area due to the occurrence of lesions, leading to poor plant development and grain filling. Of the various methods adopted for disease management, fungicides are undoubtedly the major and most practical means of effective and reliable control. Recently, several fungicides *viz.,* propiconazole, fenarimol, bupirimate, penconozole, dimethomorph, triademeton, pyrazophos, hexaconazole, chlorothalonil and flusilazole were introduced in India for control of brown spot of rice. In the quest for find newer and more efficacious molecules, the present investigation was carried out using a new formulation Flint Pro 64.8 WG (Trifloxystrobin 3.5 % + Propineb 61.3 WG %). The field trial conducted during second season of October 2017 to February 2018 at TRRI indicated that Flint Pro 64.8 WG (Trifloxystrobin 3.5 % + Propineb 61.3 WG %) 70+1226 g a.i./ha (2000g/ha) dose can effectively controlled, Brown leaf spot and narrow leaf spot diseases of Rice . This dose was at par with higher dose and resulted better yield than other treatments. No phytotoxicity was observed up to the dosage of Flint Pro 64.8 WG (Trifloxystrobin 3.5 % + Propineb 61.3 WG %) 140+2452 g a.i./ha (4000g/ha), double of the effective dose.

Keywords: Kharif season, Brown spot, seedling mortality, fungicides.

EFFECT OF ORGANIC MANURE AND MICRO NUTRIENTS ON GROWTH AND YIELD OF GROUNDNUT (*Arachis hypogaea. L*)

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Abstract

The study sought to determine the effect of combined organic and micronutrient applications on groundnut performance. The field experiment was conducted in the farmer's field at Nerkunam village, Perambalur district in Tamil Nadu (geographically located at 11°43' N latitude, 78°83' E longitude) during June 2023 - September 2023 using groundnut variety VRI-2 as test crop. The experimental soil was clay loam in texture and taxonomically classified as *Typic Ustropepts.* The basic materials for the present investigation are RDF, VC, $ZnSO_4$ (0.5 %) spray solution, boron (0.1 %) spray solution and molybdenum 0.1% spray solution. The experiment was laid out in Randomized Block Design consisting with 12 treatments viz., T_1 - RDF (Control), T_2 - RDF + Vermicompost (4 t ha^{-1}), T_3 - RDF + $ZnSO_4$ 0.5%, T_4 - RDF + Boric acid 0.1%, T_5 - RDF + Ammonium Mo 0.1%, T_6 - RDF + Vermicompost (4 t ha^{-1}) + $ZnSO_4$ 0.5% , T_7 - RDF + Vermicompost (4 t ha^{-1}) + Boric acid 0.1%, T_8 - RDF + Vermicompost (4 t ha^{-1}) + Ammonium Mo 0.1%, T_9 - RDF + Vermicompost (4 t ha^{-1}) + $ZnSO_4$ 0.5% + Boric acid 0.1% , T_{10} - RDF + Vermicompost (4 t ha^{-1}) + $ZnSO_4$ 0.5% + Ammonium Mo 0.1%, T_{11} - RDF + Vermicompost (4 t ha^{-1}) + Boric acid 0.1% + Ammonium Mo 0.1%, T_{12} - RDF + vermicompost (4 t ha^{-1}) + $ZnSO_4$ 0.5% + Boric acid 0.1% + Ammonium Mo 0.1% and replicated thrice. Foliar application was done twice at flowering and peg formation stage. Recommended dose of fertilizer were delivered uniformly for all treatments. The growth parameters, yield attributes and yield were significantly influenced by vermicompost and foliar application micronutrients (Zn, B and Mo) over control. The highest values for growth parameters were recorded at the harvest stages are plant height (58.74 cm), leaf area index (4.76), chlorophyll content (2.59), number of nodules $plant^{-1}$ (31.43) and dry matter production (5290 kg ha^{-1}) with combined application of RDF + vermicompost (4 t ha^{-1}) + $ZnSO_4$ 0.5% + Boric acid 0.1% + Ammonium Mo 0.1% (T_{12}). The lowest values of all the growth parameters were recorded in control. The highest values for yield attributes namely number of pods $plant^{-1}$(30.67), number of seeds pod^{-1} (2) and yield [pod yield (2395 kg ha^{-1}), haulm yield (3250 kg ha^{-1})]

were recorded with the combined application of RDF + vermicompost (4 t ha^{-1}) + $ZnSO_4$ 0.5% + Boric acid 0.1% + Ammonium Mo 0.1% (T_{12}). The lowest values for the yield attributes and yield were recorded in control.

Keywords: Organic Manure, Crop Health, Spray Method, Yeild Increase

SUSTAINABLE MANAGEMENT PRACTICES FOR TWISTER BLIGHT OF ONION CAUSED BY *Colletotrichum gloeosporioides* BY USING SEAWEED BIOMASS

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Abstract

Onion (*Allium cepa* L.) holds significant economic importance as it is widely grown for commercial purposes globally. onion yield is reduced by twister blight disease, which is caused by *Colletotrichum gloeosporioides* . The disease can cause substantial yield losses ranging from 50 percent to 100% percent in major onion-growing areas of Tamil Nadu. *In vitro* study was carried out on the efficacy of various solvent extracts of the elite seaweeds *viz.*, *Sargassum cristaefolium, Gracilaria edulis, Ulva lactuca, Kappaphycus alvarezii* and *Caulerpa racemosa* against *C. gloeosporioides* by agar well method. Among the promising seaweeds, the methanol extract of brown seaweed of *S. cristaefolium* (10%) showed the least mycelial growth(2.43cm) when compared to control. A pot culture experiment was conducted to assess the efficacy of seaweeds against twister blight disease in onion. The result showed that all the treatments remarkably reduced the intensity of twister blight in onion. Among the different treatments, Bulb treatment with *S. cristaefolium* @ 10% + Soil drenching with *S. cristaefolium* @ 10% + Foliar spray of *S. cristaefolium* @10% effectively reduced the intensity of twister blight and recorded the lowest mean per cent disease incidence of 23.33 % which accounted for 69.39 per cent disease reduction over control. In addition, the growth parameters of the onion significantly increased the growth characters of plants, which showed increased plant height (52.64 cm), bulb fresh weight (99.74 g), bulb diameter (3.94 cm) and number of bulb (7nos.) when compared to control.

Keywords: Onion, twister blight, *Colletotrichum gloeosporioides* seaweeds, *Sargassum cristaefolium,*

EVALUATING ALTERNATE HOST PLANTS FOR IMPROVED GROWTH AND REARING PERFORMANCE OF THE ERI SILKWORM (*Samia ricini* DONOVAN)

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Abstract

The eri silkworm (*Samia ricini* Donovan) is a multivoltine and polyphagous insect traditionally reared in rural areas of India, particularly in the northeastern region. Castor is the primary and most preferred host plant for eri silkworm rearing. The present study was conducted to evaluate the suitability of alternate host plants for the growth and development of eri silkworms at the Department of Sericulture, Forest College and Research Institute, Mettupalayam, Tamil Nadu. The C2 breed was reared on castor (YRCH 1 and local variety) and selected alternate host plants, including tapioca, jatropha, Indian badam, Arjuna, barkesseru, Chambac, Bixa and Cassia. The experiment was conducted using a Completely Randomized Design with three replications, each comprising 50 larvae. Alternate host plants were provided during the first and second instars, followed by castor leaves from the third to fifth instars. Host preference, larval duration and effective rate of rearing (ERR) were recorded to assess rearing performance. Castor recorded the highest host preference (100%), the shortest larval duration (19 days) and the highest ERR (98%), followed by tapioca, with 90% host preference, 21 days of larval duration and 90% ERR. Among the other alternate hosts, barkesseru recorded an ERR of 67%, followed by jatropha (66%), Indian badam (62%) and Arjuna (61%). Chambac recorded 40% host preference and an ERR of 45%, while Bixa and Cassia were not accepted as feed under the experimental conditions. The results indicate that tapioca is a promising alternate host for early-instar eri silkworm larvae, whereas castor remains essential for successful completion of larval development and cocoon production. The findings suggest that suitable alternate host plants can supplement castor feeding during the early instars and may help improve the flexibility of eri silkworm rearing.

Keywords: Eri silkworm, *Samia ricini*, alternate host plants, castor, tapioca, larval development, effective rate of rearing.

INNOVATIONS IN AGRICULTURAL AND BIOLOGICAL SCIENCES FOR SUSTAINABLE CROP PROTECTION

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Abstract

Sustainable crop protection is evolving through innovations in genetics, seeds and biological solutions. These technologies help agriculture boost resilience, reduce environmental impact and optimize productivity. Collaboration across research, industry and farming communities is key to adopting them effectively. Advances in genetics and seed technologies are transforming agriculture by boosting crop resilience to pests, diseases and environmental stresses, enabling nutrient use efficiency for higher yields with more sustainable crop protection production. 'Gene editing and enhanced seed traits, such as disease and herbicide resistance and climate stress tolerance, improve pest and weed management, support sustainable chemical use, promote efficient water use and improve soil health. These innovations also enable conservation practices like reduced tillage, preserving moisture and organic matter, preventing erosion and protecting biodiversity.

Biopesticides and biofungicides are natural alternatives to traditional chemical pesticides. Biopesticides faces persistent challenges such as regulatory inconsistencies, limited farmer awareness, variable efficacy and supply chain constraints. Divergent regulations often require repetitive testing and lengthy approvals, delaying market entry. Sensitivity to environmental conditions can cause inconsistent performance, while many growers remain unfamiliar with their use in pest management. Supply, storage, and distribution issues further limit access, particularly in remote areas. Overcoming these barriers requires coordinated actions *viz*., harmonized, science-based regulations with standardized data packages, large-scale trials to build trust and validate efficacy, farmer training and extension services for integration into IPM and stronger supply chains with modern infrastructure. Digital advisory tools, such as region-specific farm guidance, can further support adoption by improving application timing and dosage. Despite challenges, biopesticides offer clear advantages. Their biodegradability, target specificity and ability to reduce pesticide resistance make them valuable for both horticulture and field crops. While their narrow pest focus can complicate management, integration into

IPM turns this specificity into an advantage by minimizing non-target impacts and supporting ecological balance. Genetic advances stack resistance and tolerance traits that reduce pest and disease pressure, lower dependence on chemical inputs and help slow the development of resistance. Improved coatings and priming technologies strengthen emergence and early vigor, while breeding for enhanced root traits builds stronger relationships with beneficial microbes. Stress-tolerant varieties for heat, drought and salinity safeguard yields under increasingly variable climate conditions. Usage of humic acids, unlock soil nutrients and improve fertilizer efficiency, while seaweed extracts boost stress resilience and plant health. Together, these tools reduce emergency pesticide applications, cut costs and support stable yields. Rapid advances in genome editing, especially CRISPR, have enabled precise, faster crop improvements than traditional breeding. Coupled with AI-driven bioinformatics and availability of fast and economic genome sequencing, these tools unlock new genetic pathways for climate-resilient, resource-efficient, high-yielding crops. Integrating AI and biotechnology optimizes breeding, accelerates innovation, and combined with responsible farming, makes agriculture more efficient, sustainable, and environmentally friendly. Collaboration among researchers, policymakers and farmers will further accelerate adoption, helping agriculture adapt to climate challenges.'Clear communication on risk, safety and environmental impact builds trust with regulators and policymakers. Farmer adoption requires practical, field-tested solutions integrated into existing practices, supported by training, demonstrations and extension services. Market-driven sustainability programs and industry initiatives further encourage adoption by showing long-term value. Collaboration among agribusinesses, researchers and farmer organizations provides localized data and best practices for IPM integration, while digital platforms and real-time advisory services help farmers make informed decisions.

Keywords: Biopesticides, Humic acids, CRISPR, Biotechnology, IPM, Sustainable Agriculture

FIELD EFFICACY OF NEW INSECTICIDES FOR THE MANAGEMENT OF NEW INVASIVE THRIPS, *Thrips parvispinus* (KARNY) IN MANGO

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Abstract

Field experiments were conducted at Regional Research Station, Paiyur, Krishnagiri District. Regional Research Station , Paiyur of Krishnagiri District during 2022- 2023 to test the field efficacy of insecticides against new invasive thrips, *Thrips parvispinus* in mango (Var: Bangalora) during 2023. The field experiment was laid out in a randomized block design with five treatments, T1: Flonicamid 50 WG @ 0.3g/l, T2: Tolfenpyrad 15 EC @ 20ml/10 l. T3: Spinosad 45 SC @ 0.5ml/l T4: Imidacloprid 17.8.SL @ 0.3ml/l T5: Untreated check with five replications in each replications three trees with five panicles / tree. The regular package of practices were followed and the treatments were imposed twice after recording pre treatment count on number of thrips per panicle and further observations were recorded on 7th and 14th days after spraying (DAS) the data were statistically analyzed and compared. Experimental Results: The population of thrips ranged from 20.10 to 25.70 thrips per panicle and was found to be non significant before imposing the treatments. At 7 days after spraying (DAS), Tolfenpyrad 15 EC @ 2 ml/10 liter resulted in higher reduction of thrips population of 7.87 /panicle followed by Flonicamid 50 WG @0.3g/l (13.64/panicle) and Spinosad 45 SC@0.5ml/l. (15.10/panicleand Imidacloprid 17.8 SL @ 0.3ml/l (16.98 /panicle) where in control it was 33.38 /panicle. During 14 DAS, the population flare up in Imidacloprid 17.8 SL @ 0.3ml/l and untreated control (18.60 and 52.17/panicle), but was less in Tolfenpyrad 15 EC @ 2 ml/10 l (11.06/panicle) compared to Flonicamid 50 WG @0.3g/l (17.14 /panicle) and Spinosad 45 SC@0.5ml/l. (18.15 /panicle) (Table 1). The percent reduction over control was high in Tolfenpyrad 15 EC @ 2 ml/10 l (77.86%) followed by Flonicamid 50 WG @0.3g/l (64.02%), Spinosad 45 SC@0.5ml/l. (61.12 %) and Imidacloprid 17.8 SL @ 0.3ml/l (58.41%).After the second round of insecticides the same trend in reduction of the population of thrips in the panicle was observed, where the mean population was found to be less in Tolfenpyrad 15 EC @ 2 ml/10 liter (7.11/panicle) compared to Flonicamid 50 WG @0.3g/l

(15.31/panicle), Spinosad 45 SC@ 0.5ml/l. (16.57/panicle) and Imidacloprid 17.8 SL @ 0.3ml/l 17.51/panicle) and untreated (56.43/panicle) at 7 days after spraying. At 14 DAS, lowest thrips was recorded in Tolfenpyrad 15 EC @ 2 ml/10 liter (5.55 /panicle) this was followed by Flonicamid 50 WG @0.3g/l (10.96/panicle), Spinosad 45 SC@ 0.5ml/l. (12.08 /panicle) and Imidacloprid 17.8 SL @ 0.3ml/l (15.59/panicle) and untreated (59.70/panicle) at14 days after spraying. The percent reduction over control after second spray was maximum in Tolfenpyrad 15 EC @ 2 ml/10 l (88.34%) followed by Flonicamid 50 WG @0.3g/l (75.80%), Spinosad 45 SC@ 0.5ml/l. (86.49 %) and Imidacloprid 17.8 SL @ 0.3ml/l (76.20%). Yield harvested was significantly highest from Tolfenpyrad 15 EC @ 2 ml/10 liter 55.55 kg / tree with higher BC ratio (1.44) followed by Flonicamid 50 WG @0.3g/l (75.80%) 48.10 kg / tree with BC ratio (1.24) and Spinosad 45 SC@ 0.5ml/l.(47.22 kg / tree) and untreated check (23.20 kg / tree) was recorded.

Keywords: New Insecticides, Mango thrips, management

SEASONAL INCIDENCE OF MAJOR INSECT PESTS OF PADDY IN RELATION TO WEATHER PARAMETERS IN KRISHNAGIRI DISTRICT

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Abstract

A field experiment was conducted with paddy (variety Paiyur to study the seasonal incidence in paddy during the year 2022-2023 at Regional Research Station, Paiyur . The experiment plot was kept in unprotect condition throughout the cropping period. Observations were recorded on the pest like thrips, brown plant hoppers, green leaf hopper, leaf folder, stem folder ear head bug and natural enemies (spiders and Coccinellids) at weekly interval from 15 days from. Meteorological data during the study period was collected from Observatory Regional Research Station, Paiyur. Light trap and Pheromone traps were installed for yellow stem borer. The septa were changed once in 21 days. The sap sucking insects ranged from thrips (0.15 to 16.28 Nos./ hill), brown plan hoppers (0.78 to 11.34 Nos./ hill), green leaf hoppers (0. 486to 7.35 Nos./ hill Peak activity of thrips, brown plan hoppers and recorded in 51rd standard week (SW) thrips (16.28 Nos/ hill) brown plan hoppers at 50th standard week (11.34 Nos / hill) and green leaf hopper 50th standard week (7.35 Nos/ hill). The peak activity of gall midge and leaf folder were also observed during 47th standard week (7.32 % silver shoot damage) and 50th standard week (1.44 larva / hill) and it was ranged from 0.72 to 1.44 larva./hill). The damages of yellow stem borer dead heart and white ear were recorded and it was ranged from 5.60 to 10.48 % dead heart and white ear ranged from 7.15 to 11.30 %). Peak activity of ear head bug was recorded at 52 nd 50th standard week (0.98 Nos/ hill) . The natural enemies were ranged from spiders (0.34 to 11 Nos) and coccinellids (0.00 to 0.19 Nos / hill) was observed. Results of light trap catches. The brown plant hopper population was more (309 Nos.) during the month November followed by December (261 Nnos.) and January (111 Nos.). The green leaf hopper population was more during December (261 Nos) followed by November (211.0 Nos) The yellow stem adult moths collected more during December (102 Nos)and January(96 Nos) and less during August. The predator's population was during December (124 Nos). Results of correlation of weather parameters with light trap catches

insect and natural enemies pests**.** The green leafhopper population was positively correlated with maximum and minimum temperature, rainfall and relative humidity and Brown plant hopper was positively correlated with maximum and minimum temperature, rainfall and relative humidity. The mean population of yellow stem borer negatively correlated with temperatures and leaf folder adults was positively correlated with maximum temperature relative humidity, rainfall and negatively correlated with minimum temperature. The Coccinellids beetles were positively correlated to all weather parameters.

Keywords*:* Seasonal incidence – insect pests of paddy - weather parameters

SUSTAINABLE CONTROL OF MULBERRY AND ERI SILKWORM PESTS USING BOTANICAL FORMULATIONS: IMPLICATIONS FOR COCOON YIELD AND SEED PRODUCTION

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Abstract

Pest damage in sericulture reduces mulberry leaf quality and, in turn, larval health and cocoon output. Some chemical insecticides cause high silkworm mortality, while plant-derived oils offer safer options. Essential oils of Artemisia annua suppress the mulberry pyralid Glyphodes pyloalis, and 1% neem oil controlled leaf webber on mulberry with low silkworm mortality. However, botanical oils are often limited by poor stability and short residual activity. Nanoemulsions, with droplets typically below 300 nm, can improve dispersion and lower the effective dose; for pyrethrum extract against *Myzus persicae*, a nanoemulsion reduced the repellent dose from 0.131% to 0.025% compared with a macroscopic emulsion. Studies of nanoparticles on eri silkworm have examined toxicity, but botanical nanoemulsions against eri and mulberry pests remain poorly documented. This study will formulate selected essential oils as nanoemulsions and evaluate their toxicity against key pests of mulberry (Morus spp.) and eri silkworm (Samia cynthia ricini), measuring pest mortality, residual activity, and effects on larval survival, cocoon weight, shell ratio, and seed quality. Nanoemulsion formulations are expected to give longer residual activity at lower doses than crude extracts without impairing silkworm development at recommended concentrations. The findings will inform low-risk pest management packages for eri culture in Tamil Nadu and Puducherry.

Keywords: Botanical insecticides; Nano-emulsion; Eri silkworm; Mulberry pests; Sericulture; Sustainable crop protection

BIOCONTROL POTENTIAL OF RHIZOSPHERE ANTAGONIST BACTERIA AGAINST *Macrophomina phaseolina* CAUSING DRY ROOT ROT OF BLACK GRAM

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Abstract

Dry root rot caused by *Macrophomina phaseolina* is an important soil-borne disease affecting black gram (*Vigna mungo* L.) and can cause considerable yield losses under favourable environmental conditions. The present study was undertaken to evaluate the biocontrol potential of rhizosphere antagonist bacteria against *M. phaseolina* causing dry root rot in black gram. Diseased samples were collected from different black gram-growing regions of Tamil Nadu, and the associated pathogen was isolated and identified based on cultural, morphological and molecular characteristics. Among the isolates obtained, the highly virulent isolate was selected for further studies. Rhizosphere bacterial isolates were screened for their antagonistic activity against *M. phaseolina*, and three effective bacterial isolates, namely Try 2, SLM2 and SLM4, were selected based on their biocontrol potential. The selected isolates were identified as *Bacillus subtilis* and *Klebsiella pneumoniae* based on molecular characterization. A consortium of the effective bacterial isolates was further evaluated through seed treatment and soil application under controlled conditions. The effectiveness of the treatments was assessed based on seed germination, root and shoot growth, dry matter production and biochemical parameters. The bacterial consortium showed promising potential in suppressing the pathogen and promoting plant growth. The study indicates that rhizosphere antagonist bacteria can serve as an environmentally compatible component of integrated disease management for sustainable management of dry root rot in black gram.

Keywords: Black gram, *Macrophomina phaseolina*, dry root rot, rhizosphere bacteria, *Bacillus subtilis, Klebsiella pneumoniae*.

PREDICTING CLIMATE-DRIVEN SHIFTS IN THE POTENTIAL DISTRIBUTION OF *Bactrocera dorsalis* (ORIENTAL FRUIT FLY) IN INDIA USING ECOLOGICAL NICHE MODELLING FOR RESILIENT FRUIT FLY MANAGEMENT

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Abstract

Bactrocera dorsalis (Hendel) (Diptera: Tephritidae) is a highly destructive polyphagous pest of mango, guava, citrus, banana and many other fruit and vegetable crops in India. Climate change is expected to alter where it can establish and how severe its damage will be, so climate-informed pest management is essential for resilient plant protection. This study used ecological niche modelling (ENM) with MaxEnt to predict the potential distribution of B. dorsalis across India under present and future climate scenarios. Georeferenced occurrence records were compiled from GBIF and published literature and spatially thinned to reduce sampling bias. Bioclimatic variables from WorldClim were screened for multicollinearity, and model settings were tuned with ENMeval. Model performance was evaluated using AUC and [CBI/TSS]. Future projections were generated under [CMIP6 scenarios, e.g. SSP2-4.5 and SSP5-8.5] for [time periods, e.g. 2050s and 2070s]. Under current conditions, [X]% of India was predicted as suitable, with the highest suitability in [states/regions]. Future projections indicated [expansion/contraction/northward shift] of suitable habitat, with [regions] emerging as new high-risk areas. [Key variables, e.g. temperature seasonality, annual precipitation] contributed most to the model. These findings can guide targeted surveillance, early warning, area-wide management and region-specific IPM planning for fruit flies. The study supports science-based, climate-smart approaches to sustainable crop protection.

Keywords: *Bactrocera dorsalis*, ecological niche, climate change, fruit fly management.

DUAL-PURPOSE BOTANICAL FORMULATIONS FOR PEST SUPPRESSION AND PLANT DISEASE MANAGEMENT

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Abstract

Agriculture is increasingly challenged by insect pest outbreaks, plant diseases, pesticide resistance and the adverse environmental consequences of excessive synthetic pesticide use. These challenges threaten crop productivity, food security and the sustainability of agricultural ecosystems. In this context, botanical formulations derived from medicinal plants, aromatic plants and other bioactive plant resources are gaining attention as promising alternatives for sustainable crop protection. Their diverse phytochemicals, including terpenoids, phenolics, alkaloids and flavonoids, exhibit a range of biological activities, such as insecticidal, repellent, antifeedant, antifungal and antibacterial effects. The development of dual-purpose botanical formulations that target both insect pests and plant pathogens represents an innovative approach to integrated crop health management, potentially reducing the need for separate pest and disease control inputs. Essential oils and plant extracts from species such as *Azadirachta indica*, *Cymbopogon citratus*, *Ocimum spp*. And *Eucalyptus spp*. Have been investigated for their potential insecticidal and antimicrobial properties. However, their effectiveness varies with plant species, chemical composition, extraction methods, target organisms and application conditions. Emerging formulation technologies, particularly nanoemulsions, may improve the dispersion, stability and delivery of poorly water-soluble botanical compounds, although their benefits must be validated through appropriate laboratory and field studies. Integrating these formulations with biological control, crop rotation, resistant varieties and other integrated pest management practices may support more effective and environmentally responsible crop protection. Despite their potential, several challenges remain, including variability in botanical composition, rapid degradation under environmental conditions, phytotoxicity, effects on beneficial and non-target organisms, formulation stability and economic feasibility. Therefore, systematic evaluation of efficacy against selected insect pests and plant pathogens, together with crop safety and environmental risk assessment, is essential before recommending field application. This paper highlights the potential of dual-purpose botanical formulations, recent

formulation innovations and their possible integration into sustainable pest and disease management programmes. Further research into standardised formulations, synergistic combinations of bioactive compounds and field-level validation could facilitate the development of safer, cost-effective and climate-resilient crop protection strategies. Overall, botanical formulations offer a promising research pathway towards reduced dependence on synthetic pesticides, improved crop health and more resilient agricultural systems.

Keywords: Botanical formulations, nanoemulsions, antimicrobial activity, integrated pest management, sustainable crop protection.

DIGITAL TECHNOLOGIES FOR CROP HEALTH MONITORING

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Abstract

Digital technologies are emerging as important tools for improving crop health monitoring and sustainable plant disease management. Plant diseases significantly affect crop yield and quality, creating a need for accurate, timely and efficient methods of disease detection and assessment. Conventional visual monitoring methods can be influenced by observer variability and may not provide sufficient precision for large-scale agricultural systems. Recent advances in digital agriculture, including optical sensors, multispectral and hyperspectral imaging, robotics, unmanned aerial vehicles (UAVs) and artificial intelligence (AI), have created new opportunities for automated and non-invasive plant disease detection. These technologies enable the identification and quantification of disease symptoms, monitoring of disease progression and assessment of crop health under laboratory, greenhouse and field conditions. AI-based image analysis and machine learning algorithms facilitate the classification of plant disease symptoms, while sensor-equipped robotic platforms support large-scale and site specific crop monitoring. Integration of sensor-derived information with epidemiological and environmental data can improve disease risk assessment and support decision-making in integrated disease management (IDM). Furthermore, digital disease assessment can facilitate targeted plant protection applications, potentially reducing unnecessary pesticide use and associated environmental impacts. Despite these advances, challenges remain in achieving reliable detection under variable field conditions, improving data quality, validating diagnostic accuracy and transferring research innovations into practical agricultural applications. High implementation costs, limited technical expertise and the need for farmer education also influence adoption. Therefore, integrating digital technologies with conventional plant pathology expertise and integrated disease management practices is essential for advancing precision crop protection and sustainable agricultural production.

Keywords: Digital agriculture, optical sensors, artificial intelligence, robotics, plant disease detection, crop protection.

ENGINEERING THE PLANT MICROBIOME: EMERGING BIOTECHNOLOGICAL STRATEGIES FOR SUSTAINABLE CROP PROTECTION

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Abstract

Microbial biotechnology has emerged as a promising approach for improving crop protection, enhancing agricultural productivity, and promoting sustainable farming practices. The review article, Microbial Biotechnology: Innovations for Crop Protection and Improvement, discusses the applications of beneficial microorganisms and advanced biotechnological techniques in modern agriculture. Microorganisms, including bacteria, fungi, and viruses, play important roles in maintaining soil health, improving nutrient availability, promoting plant growth, and suppressing plant pathogens. In addition to microbial applications, the review discusses advanced biotechnological approaches that can contribute to crop improvement. Techniques such as cisgenesis, genome editing using CRISPR-Cas systems, and RNA interference (RNAi) have potential applications in developing crops with improved resistance to pathogens and tolerance to environmental stresses. These technologies may support the development of improved crop varieties with desirable characteristics, contributing to enhanced productivity and reduced crop losses. The integration of microbial biotechnology with modern genetic techniques offers new opportunities for addressing agricultural challenges and improving the efficiency of crop production systems. Further development and application of these approaches may help reduce the environmental impacts associated with conventional agricultural practices, conserve natural resources, and support long-term food security. The integration of microbial biotechnology into crop production systems therefore offers valuable opportunities for developing more resilient, productive, and environmentally sustainable agricultural systems.

Keywords: Biotechnology, biocontrol, CRISPR-Cas, RNA interference, crop protection, sustainable agriculture.

SURVEY ON INSECT PESTS OF FRUIT CROPS IN KRISHNAGIRI DISTRICT

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Abstract

A roving survey of emerging insect pests of fruit Crops in Krishnagiri district was conducted at farmers' fields in the blocks of Krishnagiri, Hosur, and Kaveripattinam by scientists of the Regional Research Station, Paiyur, Krishnagiri district during 2024-2025. Four villages will be selected in each block in Krishnagiri district for monitoring the pest population in fruits like Mango, Sapota, Pomegranate at 15 days interval of month from December 2024 to March 2025 during the cropping period. The results of mango leaf hoppers ranging from (0.60 to 3.05/3 leaves), mango looper (0.10 to 0.50 nos/flowers) and thrips (1.65 to 7.20/ panicle) and stem borer larvae 2 nos/plant, recorded in mango ecosystem in Krishnagiri district. In result of sapota, the leaf webber larvae & Fruit borer incidence was recorded (1.09 to 2.14 nos/plant) & (8 to 32 %) in orchard. In pomegranate fruit, the fruit borer damage was recorded, and it ranged from 24 to 36 per cent in the pomegranate ecosystem.

Keywords: Roving survey, Mango, Sapota, Pomegranate

FRONT LINE DEMONSTRATION ON THE MANAGEMENT STRATEGY FOR WHITEGRUB IN SUGARCANE

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Abstract

The Front-line demonstration experiment was conducted in farmers holding during 2024-2025 in view to develop ecofriendly strategies for the management of white grub in sugarcane crop. Various bio inoculants with required dose per hectare were prepared and multiplied in well decomposed farm yard manure of 50 kgs and mixed with 2500 kgs of decomposed FYM at the time of application for easy handling and applied near root zone during earthing up (during May/June). The FLD field experiment was conducted in 5 location at Dharmapuri district farmer field during 2024-2025. The treatments include as T1 Enriched *Metarhizium anisopliae* -2kg/acre, Installation of light trap 1 No./ha, Imidacloprid 17.8 SL -100 ml/acre, T2. Farmer practice. The population of white grub/clump was found low population in IPM plot (0.58 Nos of white grub/clump) than farmer practice (2.72 Nos of whitegrub/ clump). The yield and BCR was found that highest in IPM plot (118.8 Mt/ha and 2.82) than farmer practice (79.97 Mt/ha. and 1.76).

Keywords: Sugarcane, Whitegrub, FLD, *Metarhizium anisopliae*

RESILIENCE STRATEGIES FOR SUSTAINABLE AGRICULTURE, CROP HEALTH AND PLANT PROTECTION

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Abstract

Agriculture is increasingly threatened by climate change, extreme weather events, soil degradation, emerging plant diseases, and insect pest infestations, which adversely affect crop productivity and food security. Developing resilient and sustainable agricultural systems is essential to ensure long-term agricultural sustainability and environmental protection. This review highlights various resilience strategies for sustainable agriculture, with particular emphasis on crop health and plant protection. Key approaches include climate-resilient crop varieties, crop diversification, conservation agriculture, integrated pest management (IPM), biological control, and the application of plant growth-promoting rhizobacteria (PGPR) and other beneficial microorganisms. Furthermore, induced plant resistance and eco-friendly biopesticides offer promising alternatives to excessive chemical pesticide use by enhancing plant defence mechanisms and reducing environmental risks. Sustainable soil and water management practices also contribute to improved crop growth and tolerance to abiotic stresses such as drought, salinity, and high temperatures. Integrating traditional agricultural knowledge with modern technologies can further strengthen farming systems against environmental and biological challenges. However, the adoption of these strategies may be limited by economic constraints, inadequate awareness, and insufficient access to appropriate technologies. Therefore, an integrated, ecosystem-based approach combining sustainable farming practices, biological crop protection, and climate adaptation is essential for maintaining crop health, reducing crop losses, conserving biodiversity, and ensuring long-term food security.

Keywords: Agricultural resilience, Plant protection, Integrated pest management, Biological control, Biopesticides; Plant disease management; Induced resistance

SCIENTIFIC PERSPECTIVES ON INDIGENOUS BOTANICALS FOR SUSTAINABLE SEED STORAGE AND PEST MANAGEMENT

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Abstract

Effective seed storage management aims to minimize insect infestation while maintaining seed viability, germination percentage, vigour, physical purity and overall physiological quality throughout the storage period. Insect damage may cause seed weight loss, embryo injury, reduced germination, deterioration of seed vigour, thereby affecting planting value and crop establishment. Seed deterioration during storage is influenced by temperature, relative humidity, seed moisture content, packaging materials and storage duration. Botanicals have been used traditionally as eco-friendly alternatives to synthetic pesticides for protecting stored grains and seeds against insect pests. Plant-derived bioactive compounds, including alkaloids, flavonoids, terpenoids, phenolics, tannins, essential oils, may exhibit insecticidal, repellent, antifeedant, oviposition-deterrent and insect growth-regulating properties. These compounds can interfere with insect feeding behaviour, reproduction and physiological processes, thereby helping to suppress pest infestation and population development during storage. Indigenous knowledge regarding the use of different plant parts, such as leaves, seeds, roots, bark, and fruits extracts represents a valuable source of locally available and cost-effective pest management strategies. Documenting these traditional practices can help bridge the gap between indigenous knowledge and modern scientific approaches. Integrating scientifically validated botanical practices into integrated pest management (IPM) and sustainable seed storage systems may reduce dependence on synthetic insecticides, minimize chemical residues and support environmentally responsible seed conservation. Further scientific evaluation of botanical efficacy, application methods, and their effects on seed germination, vigour and storability is essential for their effective utilization in seed technology and stored-product pest management.

Keywords: Botanicals, Indigenous knowledge, Seed storage, Stored-grain pests and Seed viability.

ADVANCES IN INTEGRATED PEST MANAGEMENT FOR RESILIENT CROP PRODUCTION

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Abstract

Agricultural production faces increasing pressure from insect pests, pesticide resistance, climate variability and the need to protect human health and biodiversity. Innovation in agricultural and biological sciences offers practical ways to manage these challenges while maintaining crop productivity. Entomology contributes to sustainable crop protection by improving understanding of pest biology, population dynamics, natural enemies and interactions within agroecosystems. Integrated pest management (IPM) provides a framework for combining compatible control methods according to pest monitoring and economic thresholds, rather than relying on routine pesticide use. Current approaches include biological control using predators, parasitoids and entomopathogenic microorganisms; botanical and microbial biopesticides; pheromones for monitoring, trapping and mating disruption; and crop varieties with resistance or tolerance to pests. Cultural practices such as crop rotation, intercropping, sanitation and habitat management can prevent pest outbreaks and support beneficial insects. Together, these methods can reduce unnecessary pesticide applications while helping conserve natural enemies and other non-target organisms.fao+2Digital technologies are also expanding the options available to entomologists and farmers. Sensors, remote monitoring, image-based pest identification and data-supported decision tools can help detect pest activity and guide timely, targeted interventions. Precision application technologies may further improve the placement and efficiency of crop-protection products. These innovations are most effective when adapted to local crops, pest species and farming conditions, and when supported by field research, farmer training and collaboration among researchers, extension workers and growers. Sustainable crop protection therefore depends not on a single technology, but on combining biological knowledge, ecological management and appropriate modern tools. By integrating these innovations within IPM, entomology can support resilient agricultural

systems, reduce dependence on broad-spectrum pesticides, and contribute to long-term food security and environmental health.

Keywords: Entomology; integrated pest management; sustainable crop protection; biological control; biopesticides; pheromone-based management; precision agriculture; natural enemies.

SUSTAINABLE LIGNIN-REINFORCED PLA BIOCOMPOSITES: ECO-FRIENDLY MATERIALS FOR NEXT-GENERATION AGRICULTURAL MULCHING

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Abstract

Agricultural mulching conserves soil moisture, moderates soil temperature, suppresses weeds, and supports crop productivity. The Food and Agriculture Organization (FAO) estimated that agricultural value chains used 12.5 million tonnes of plastic annually in plant and animal production. At the same time, demand for greenhouse, mulching, and silage films was projected to increase by 50% between 2018 and 2030. These trends highlight the need for alternatives to conventional petroleum-based plastic films, which can leave persistent residues in agricultural environments. Polylactic acid (PLA) offers a biodegradable polymer matrix for mulch-film development, while lignin was selected as a renewable, multifunctional component because its aromatic structure absorbs ultraviolet (UV) radiation and its incorporation can influence the mechanical, thermal, and antimicrobial properties of the resulting biocomposites. Lignin microparticles (LMPs) derived from *Borassus flabellifer* leaves also provide a potential value-added application for locally available plant biomass. Among the evaluated formulations, PLA containing 8 wt% LMPs exhibited a water contact angle of 105.2°, indicating a hydrophobic surface. UV transmission decreased from approximately 47% for PLA to 9% for the lignin-containing composite, while tensile strength increased from 12.1 to 17 MPa. The composite also demonstrated antibacterial activity against *Staphylococcus aureus* and *Escherichia coli*. Fourier-transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), and X-ray diffraction (XRD) were used to characterize the chemical features, morphology, and structural properties of the composites. Under the evaluated experimental conditions, plant height reached approximately 82.23 cm, and fruit production was about 475 g for PLA-LMP, which was comparatively higher than that of PLA mulch. These findings indicate that incorporating lignin can improve selected functional properties of PLA-based agricultural mulch materials. Using *B. flabellifer* leaves as a lignin feedstock could also create opportunities for rural biomass collection, aggregation, and supply to processing units, where trained personnel could undertake lignin extraction and microparticle production. Linking local

biomass resources with biocomposite manufacturing may support small-scale rural enterprises while providing biodegradable mulch materials for agricultural communities, particularly in water-limited regions where soil-moisture conservation is important. Further research should assess soil biodegradation, field-scale performance, long-term environmental effects, life-cycle impacts, and production costs to establish the practical feasibility of these materials and their potential contribution to sustainable agriculture.

Keywords: Biodegradable mulch, *Borassus flabellifer*, polylactic acid, lignin microparticles, UV-barrier property

BIOCHEMICAL MECHANISMS OF MICROBIAL BIOCONTROL FOR SUSTAINABLE PLANT DISEASE MANAGEMENT

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Abstract

Plant diseases are still a threat to the sustainability of the environment, food security, and agricultural productivity. Concerns about pathogen resistance, environmental pollution, and negative effects on beneficial microorganisms have been brought up by the widespread use of chemical pesticides. Microbial biocontrol has become a viable and environmentally responsible method for managing plant diseases in a sustainable manner. The main biochemical and biological processes by which beneficial microorganisms reduce plant diseases and improve crop health are examined in this review. The production of antimicrobial metabolites, hydrolytic enzymes, nutrient competition, and the induction of systemic resistance in plants are some of the ways that bacterial and fungal antagonists, such as *Bacillus and Trichoderma* species, help to suppress disease. The functions of chitinases, glucanases, lipopeptides, and other bioactive substances in preventing infection and pathogen growth are examined. It is also investigated how these mechanisms might be used to control soil-borne illnesses, specifically *Fusarium* basal rot of onions. The review also identifies current obstacles to the application of biocontrol, such as variable field performance, environmental factors, formulation constraints, and microbial community interactions. The reliability of biological control strategies may be increased by incorporating advanced molecular techniques, microbial consortia, and biochemical characterization. Enhancing agricultural resilience, reducing reliance on chemical fungicides, and developing sustainable crop protection techniques can all be facilitated by a deeper comprehension of plant-microbe-pathogen interactions.

Keywords: Microbial biocontrol, biochemical mechanisms, *Bacillus, Trichoderma, Fusarium,* plant disease management, sustainable agriculture.

RNA BIOPESTICIDES: FROM GENE SILENCING TO FIELD-READY INNOVATIONS FOR SUSTAINABLE CROP PROTECTION

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Abstract

RNA interference (RNAi) is a naturally occurring, sequence-specific gene-silencing mechanism in which double-stranded RNA (dsRNA) triggers degradation or suppression of complementary messenger RNA, thereby reducing the expression of essential genes. Its high sequence specificity and potential to target essential biological processes in pests have positioned RNAi as an emerging alternative to conventional broad-spectrum pesticides. Following the demonstration of RNAi-mediated gene silencing in *Caenorhabditis elegans*, subsequent research established its potential in agricultural pest management through oral delivery, transgenic plants and, more recently, spray-induced gene silencing (SIGS). In SIGS, externally applied dsRNA is taken up by target organisms and induces sequence-specific suppression of selected genes without requiring genetic transformation of the crop. In maize, RNAi has been extensively investigated against western corn rootworm, *Diabrotica virgifera*, leading to the development of RNAi-based crop-protection technologies. In potato, spray-applied dsRNA targeting essential genes of Colorado potato beetle, *Leptinotarsa decemlineata*, progressed from laboratory and field research to the development of ledprona, the first sprayable dsRNA insecticide registered in the United States. Recent research has expanded sprayable RNAi applications to additional pests, including *Thrips palmi*, *Phyllotreta striolata*, *Tuta absoluta*, *Helicoverpa armigera, Bemisia tabaci* and several lepidopteran and hemipteran pests. Recent studies have demonstrated the potential of spray-applied dsRNA against *T. palmi* and field evaluation of formulated RNA biopesticides against *P. striolata*. A major challenge in translating RNAi into practical pest management is the efficient delivery and persistence of dsRNA. Naked dsRNA is vulnerable to degradation by ultraviolet radiation, environmental nucleases and other abiotic factors, which can substantially reduce its biological activity. Nanoparticle-based delivery systems have therefore emerged as an important innovation for improving dsRNA stability, protection and uptake. Different materials, including clay and layered double hydroxide nanoparticles, chitosan, liposomes, carbon-based materials, gold nanoparticles and silica, have been investigated as potential dsRNA carriers. Surface functionalization using oligonucleotides, lipids, polymers, proteins and peptides can further

improve stability, cellular uptake, controlled release and target specificity. These approaches provide opportunities to transform unstable naked dsRNA into more persistent and effective RNA-based bio inputs suitable for crop-protection applications.

Keywords: RNAi, spray-induced gene silencing, ledprona, abiotic factors, delivery systems

FROM WEED SUPPRESSION TO INSECT PROTECTION: MULTIFUNCTIONAL BOTANICAL BIOPESTICIDES FROM *Ocimum tenuiflorum, Calotropis gigantea and Prosopis juliflora* AGAINST *Echinochloa colona* AND MAJOR RICE INSECT PESTS

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Abstract

The intensive reliance on synthetic pesticides in rice production has created an urgent need for innovative, environmentally responsible and multifunctional crop-protection strategies. In this context, the present study investigated the potential of *Ocimum tenuiflorum*, *Calotropis gigantea* and *Prosopis juliflora* as botanical biopesticides for integrated suppression of the major rice weed *Echinochloa colona* and potential protection against insect pests. Methanolic and hexane extracts of the botanicals were evaluated for phytotoxic activity, and the promising methanolic extracts were further investigated under field conditions. Eco-friendly botanical EC formulations were evaluated through field treatments comprising pre-emergence application at 3DAS,post-emergence application at 20 DAS and supplementary hand weeding at 35 DAS for their effectiveness in reducing weed density and dry weight and improving weed control efficiency. The established evaluation identified 10% methanolic *O. tenuiflorum* 50% EC as the most promising botanical treatment for suppression of *E. colona.* The multifunctional potential was further explored through assessment of major rice insect pests, namely brown planthopper (*Nilaparvata lugens*), green leafhopper (*Nephotettix* spp.) and rice leaf folder (*Cnaphalocrocis medinalis*), following the post-emergence application. GC–MS profiling revealed diverse bioactive constituents, including methyleugenol, caryophyllene, eugenol, phytol, neophytadiene and fatty-acid derivatives. Caryophyllene, eugenol and phytol were identified as promising candidate compounds for further investigation of insecticidal and repellent-associated activity. Selected phytochemicals will be subjected to dual-target in-silico molecular docking against acetolactate synthase (ALS) and acetylcholinesterase (AChE) to

investigate their herbicidal and insecticidal modes of action, respectively. The integration of botanical weed suppression, potential insect protection, phytochemical profiling and molecular-level screening provides an innovative pathway towards multifunctional and sustainable crop protection, contributing to SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production) and SDG 15 (Life on Land).

Keywords: Botanical biopesticide; *Echinochloa colona*; rice insect pests; allelopathy; GC–MS; molecular docking; sustainable crop protection.

INNOVATIONS IN AGRICULTURAL AND BIOLOGICAL SCIENCES FOR SUSTAINABLE CROP PROTECTION

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Abstract

Agriculture faces increasing challenges from insect pests, plant pathogens, weeds, climate change, and the excessive use of chemical pesticides, which threaten crop productivity, environmental quality, and food security. Sustainable crop protection requires innovative approaches that minimize ecological damage while ensuring effective pest and disease management. Recent advances in agricultural and biological sciences have introduced several promising strategies, including integrated pest management (IPM), biological control, microbial biopesticides, plant-based pesticides, host plant resistance, molecular technologies, and precision agriculture. Biological control agents such as predators, parasitoids, and entomopathogenic microorganisms offer environmentally friendly alternatives to conventional chemical pesticides. Furthermore, innovations in biotechnology, including RNA interference (RNAi), genome editing, and molecular diagnostics, provide new opportunities for developing resistant crop varieties and improving pest detection. The integration of artificial intelligence, remote sensing, drones, and digital decision-support systems enables early pest detection, precise pesticide application, and timely management decisions. Combining these technologies with ecological approaches, such as crop diversification, habitat management, and conservation of beneficial organisms, can reduce pesticide dependency and promote agroecosystem resilience. However, challenges related to cost, accessibility, field-level effectiveness, and farmer awareness must be addressed for wider adoption. This seminar highlights emerging innovations in agricultural and biological sciences and emphasizes the importance of integrating scientific advances with sustainable farming practices to achieve effective crop protection, conserve biodiversity, and strengthen long-term agricultural sustainability.

Keywords: Sustainable crop protection, integrated pest management, biological control, biopesticides, biotechnology, precision agriculture, artificial intelligence.

HOST PLANT DIVERSITY AND INFESTATION SEVERITY OF *Aleurodicus rugioperculatus* IN MIT CAMPUS, TIRUCHIRAPPALLI, TAMIL NADU.

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Abstract

Invasive insect pests pose a significant threat to agricultural production, horticultural diversity and the natural environment. The rugose spiralling whitefly (RSW), *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae), is a highly polyphagous invasive pest that infests a wide range of economically important and ornamental plants. Knowledge of its host range, host preference, and infestation severity is essential for developing effective integrated pest management strategies. The present study was conducted at MIT Campus, Tiruchirappalli (MITCAT), Tamil Nadu, from December 2025 to June 2026, to document the host range of *A. rugioperculatus* and assess the extent of damage caused to different host plants. Systematic field surveys recorded approximately 40 plant species belonging to different botanical groups, including palms, woody ornamentals, fruit crops and other vegetation. Among the recorded infested hosts, palm species accounted for 40%, followed by *Calophyllum* spp. (10%), avocado (9%) and mango varieties (3%). Within the family Arecaceae, coconut accounted for 44% of the recorded palm host records, indicating its importance in the host distribution of the pest. Furthermore, 17 plant species belonging to 11 families were documented as preferred hosts at the study site. The extent of infestation varied considerably among host plants. Based on observed symptoms and infestation intensity, the host plants were classified into very severe, severe, moderate, and minor infestation categories. Banana plants exhibited severe leaf infestation, with approximately 25–40% of leaves affected in observed cases. Complete drying of infested leaves was also recorded at several locations, indicating substantial damage to the affected foliage. Typical symptoms associated with RSW infestation included the presence of spiralling egg-laying patterns, white waxy secretions, nymphal colonies, honeydew deposits, and the development of black sooty mould on leaf surfaces. These symptoms can interfere with photosynthetic activity and reduce the aesthetic and physiological quality of affected plants. The diversity of infested hosts observed during the survey highlights the pest's ability to establish populations across different plant families and vegetation types within the campus ecosystem. The findings emphasize the importance of regular surveillance, early detection, and

host-specific monitoring for the management of *A. rugioperculatus*. Particular attention should be directed towards coconut and other frequently infested host plants, as well as banana plants exhibiting substantial foliar damage. The study provides baseline information on the host range and field infestation of A. *rugioperculatus* in MITCAT, Tiruchirappalli, and can contribute to the formulation of ecologically sound integrated pest management practices.

Keywords: *Aleurodicus rugioperculatus*; rugose spiralling whitefly; host range; host preference; infestation severity; damage assessment.

SURVEY AND IDENTIFICATION OF NATURAL ENEMIES ASSOCIATED WITH RUGOSE SPIRALLING WHITEFLY

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Abstract

The rugose spiralling whitefly (RSW*), Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae), is an invasive, polyphagous pest that infests several economically important crops, including coconut and banana. Natural enemies play a significant role in the biological suppression of this pest and are important components of integrated pest management. The present study aimed to document the occurrence and diversity of natural enemies associated with *A. rugioperculatus* in coconut and banana ecosystems through systematic field surveys and laboratory observations. Pest-infested host plants were examined carefully by inspecting leaves, stems and other plant parts for the presence of predators and parasitoids associated with different developmental stages of the whitefly. Natural enemies were collected using hand picking, soft brushes, forceps and aspirators. Sweep net sampling was used to collect foliage-dwelling and flying beneficial insects, while the beating tray method was employed to dislodge arthropods from plant branches. Whitefly-infested leaves containing eggs, nymphs, and puparia suspected of parasitization were collected and transported to the laboratory for further examination and rearing. The survey recorded a diverse assemblage of natural enemies associated with RSW, comprising predatory insects, spiders and a parasitoid. The recorded insect predators included the green lacewing, *Chrysoperla zastrowi sillemi* (Neuroptera: Chrysopidae), and four coccinellid beetles, namely *Chilocorus nigrita, Menochilus sexmaculatus, Scymnus nubilis*, and *Coccinella transversalis* (Coleoptera: Coccinellidae). These predators were observed feeding on whitefly eggs and immature stages, particularly nymphs. The red weaver ant, *Oecophylla smaragdina* (Hymenoptera: Formicidae), was also observed actively foraging on infested plants. Among the parasitoids, *Encarsia guadeloupae* (Hymenoptera: Aphelinidae) was recovered from parasitized whitefly nymphs. Successful parasitoid emergence from infested leaves confirmed its association with *A. rugioperculatus* under field conditions. Spider predators recorded during the survey included *Olios giganteus* and *Gnathopalystes taiwanensis* (Sparassidae), C*arrhotus viduus* (Salticidae), *Peucetia viridans* (Oxyopidae), and *Thomisus spectabilis* and *Thomisus onustus* (Thomisidae). These

spiders were observed in association with infested host plants and may contribute to the predation of whiteflies and other small arthropods. The collected specimens were labelled with relevant field information, including collection date, location, host plant species, and associated pest, and were identified using standard taxonomic keys and scientific literature. The occurrence of diverse predators and the parasitoid *E. guadeloupae* indicates the presence of a naturally occurring biological control complex associated with RSW in the surveyed ecosystems. Conservation of these beneficial organisms through appropriate, environmentally sustainable pest management practices may contribute to the suppression of whitefly populations.

Keywords: *Aleurodicus rugioperculatus;* natural enemies; biological control; predators; parasitoids; integrated pest management.

DEFENCE-ASSOCIATED BIOCHEMICAL RESPONSES OF MULBERRY GENOTYPES DURING LEAF SPOT DEVELOPMENT UNDER TEMPERATE CONDITIONS OF KASHMIR

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Abstract

Leaf spot disease is an important foliar constraint affecting mulberry during late summer and autumn under temperate conditions of Kashmir. The present investigation assessed temporal changes in defence-associated biochemical constituents of ten mulberry genotypes under field conditions at the College of Temperate Sericulture, Mirgund, SKUAST-Kashmir. Leaf samples were collected fortnightly from 30 July to 15 September and analysed for total phenol, flavonoid, xanthophyll and anthocyanin contents. Considerable genotypic and temporal variation was observed in the accumulation of these metabolites. Total phenol and flavonoid contents generally increased progressively, with Goshoerami recording the highest values of 4.99 and 8.67 mg g^{-1}, respectively, on 15 September. In Goshoerami, xanthophyll increased from 1.72 to 4.69 mg g^{-1}, while anthocyanin increased from 0.099 to 0.179 mg g^{-1} during the study period. Goshoerami, Ichinose and Rokokuyoso showed comparatively greater accumulation of defence-associated metabolites, whereas Chinese White generally recorded lower levels. The progressive accumulation of these metabolites suggests activation of antioxidant and defence-associated biochemical responses during leaf spot development. The observed genotypic variation provides useful insights into the biochemical responses associated with leaf spot development in mulberry under temperate conditions.

Keywords: Mulberry, leaf spot, defence response, phenols, flavonoids, xanthophyll, anthocyanin, Kashmir

MOLECULAR DIAGNOSTICS AND EARLY DETECTION OF PLANT PATHOGENS FOR SUSTAINABLE CROP PROTECTION

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Abstract

Plant diseases are major constraints to agricultural productivity and food security, causing significant economic losses worldwide. Conventional methods of plant pathogen identification, based on symptom observation, morphological characteristics, and culture techniques, are often time-consuming and may fail to detect pathogens during the early stages of infection. Molecular diagnostic techniques have emerged as reliable tools for rapid, sensitive, and specific detection of plant pathogens, supporting timely disease management and sustainable crop protection. Techniques such as polymerase chain reaction (PCR), real-time PCR (qPCR), loop-mediated isothermal amplification (LAMP), and DNA barcoding enable the identification of fungal, bacterial, viral, and phytoplasma pathogens, including those that are difficult to detect using conventional methods. Among these approaches, qPCR facilitates pathogen quantification, whereas LAMP offers rapid detection under relatively simple laboratory conditions. Recent advances in CRISPR-based diagnostics, portable detection devices, and biosensor technologies have further expanded the possibilities for field-level pathogen identification. Early and accurate diagnosis enables the implementation of targeted management strategies, reduces unnecessary pesticide applications, and helps prevent the spread of diseases through infected planting materials and agricultural trade. Furthermore, integrating molecular diagnostics with disease surveillance, resistant crop varieties, and biological control approaches can strengthen integrated disease management programmes. Overall, molecular diagnostics provide a valuable foundation for precision plant disease management, promoting efficient crop protection, reduced environmental impact, and sustainable agricultural production.

Keywords: Molecular diagnostics, plant pathogens, early detection, PCR, qPCR, LAMP, sustainable crop protection.

SUSTAINABLE AGRICULTURE FOR HEALTH AND WELL-BEING: LINKING CROP DIVERSITY, NUTRITION AND SUSTAINABLE DEVELOPMENT GOALS

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Abstract

The agricultural sector is crucial for food security, good nutrition, human health and environmental sustainability. Nonetheless, soil erosion, climate change, loss of biodiversity and dependency on external factors impose serious risks to agricultural systems' sustainability. Crop diversification is a solution which could tackle the mentioned problems by improving the functioning of the agroecosystems as well as providing for diverse diet and better nutritional security. Combined crop diversification and crop rotation, as well as legume integration into the cropping systems, may enhance soil organic carbon, nutrient cycling, soil biota activity and resource-use efficiency and minimize negative impacts on the environment. The agriculture, nutrition and health nexus is very important because how we grow food affects the amount, access and types of food available. The way crops are grown substantially influence the extent of chemical residues entering the environment and potentially affecting human health. Soil health is fundamental to food production, as healthy soils sustain diverse biological communities and facilitate nutrient cycling and water availability. Therefore, promoting crop diversity, ecologically sustainable farming practices, and responsible soil management is essential for maintaining productive and resilient agricultural systems. Sustainable food systems and healthy diets are essential for ensuring food security, adequate nutrition, and overall human well-being. Reinforcing these interconnected areas can contribute to broader Sustainable Development Goals by promoting sustainable agricultural production, conservation of natural resources, resilient communities, and equitable and sustainable development.

Keywords: Crop diversity, Sustainable agriculture, Nutrition security, Sustainable Development Goals.

EVALUATION OF EFFECTIVE TREATMENTS FOR THE MANAGEMENT OF ANTHRACNOSE LEAF SPOT OF CULINARY MELON UNDER FARMERS' FIELD CONDITIONS

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Abstract

Anthracnose leaf spot is an important disease affecting of culinary melon. Confirmation trials were subsequently conducted during July 2015 to October 2015 at three farmers' field locations, namely Venganoor, Vavamoola, and Venjaramoodu. The two most effective treatments were evaluated and included in package of practices (POP) of KAU, farmers' management practices, and absolute control. PDI and DI, while crop performance was evaluated based on number of harvests, daily yield, average fruit yield, and total fruit yield. Among these treatments, foliar application of T2 - NPK 19:19:19 (0.5%) + azoxystrobin (0.15 ml/L) + adjuvant, consistently recorded superior performance across the three locations. At Venganoor, T2 was recorded lowest PDI (11.11%) and DI (30.00%). And also produced highest number of harvests (7.69), daily yield (4.73 kg), average fruit yield (18.94 kg), and total fruit yield (56.82 kg). At Vavamoola, T2 was recorded lowest PDI (12.77%) and DI (25.50%), harvests (8.62), daily yield (3.05 kg), average fruit yield (12.22 kg), and total fruit yield (48.87 kg). At Venjaramoodu, T2 was recorded lowest PDI (12.77%) and DI (30.00%), with the highest number of harvests (2.50), daily yield (1.31 kg), average fruit yield (3.92 kg), and total fruit yield (11.77 kg). The pooled analysis revealed that T2 (NPK 19:19:19 (0.5%) + azoxystrobin (0.15 ml/L) + adjuvant) recorded a lowest PDI (12.22%), DI (28.50%) as compared to control plot and total fruit yield (39.15 kg).

Keywords: Culinary melon, Anthracnose leaf spot, Foliar fertilizer, Azoxystrobin, Farmers' field trials

REGENERATIVE AGRICULTURE AND SUSTAINABLE PLANT PROTECTION: ENHANCING RESILIENCE THROUGH NATURAL STRATEGIES

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Abstract

The world faces increasing food, environmental, and human security issues, primarily attributed to an overburdened agricultural sector struggling to keep pace with rising population and demand for food, energy, and fiber. Advances in food production and agriculture, especially with monoculture farming, have continued to meet these demands but at a high price regarding resource depletion and environmental devastation. This is especially severe in developing world areas with rural populations with thin resource margins. Regenerative agriculture has emerged as a solution to provide shielding for food production, ensure environmental protection, and promote social equity while addressing many of these issues. Regenerative agriculture food production aims to restore soils, forests, waterways, and the atmosphere and operate with lower offsite negative environmental and social impacts. This review discusses the fundamental principles and practices of sustainable plant protection for regenerative farming. It focuses on the role of biological and ecological processes, reduces non-renewable inputs, and aims to incorporate traditional ecological knowledge into pest control practices. It offers essential transition strategies, including critical changes from conventional integrated pest management (IPM) to agroecological crop protection, focusing on systemic approaches to design agroecosystems. It also reaffirms the importance of a vast diversity of pest control methods that are culturally, mechanistically, physically, and biologically appropriate for regenerative farming practices. Ultimately, the aim is to encourage ecological, economic, and social sustainability for the future of more resilient and controlled agricultural practices.

Keywords: sustainable plant protection, regenerative agriculture, eco-friendly pest management, pest control.

ECO-FRIENDLY MANAGEMENT OF PULSE BEETLE (*Callosobruchus* sp.) USING BOTANICALS ON STORED MUNGBEAN

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Abstract

Pulse beetle, *Callosobruchus* sp. (Coleoptera: Bruchidae) has got great economic importance and most destructive in stored pulses. The preference biology and quantitative losses of pulse beetle to different botanical treatment viz., Neem leaf powder (*Azadirachta indica*), Thumbai (*Leucas aspera*), Adhathoda (*Adhatoda beddomei*), Tulsi (*Ocimum tenuiflorum*), Aloe vera (*Aloe vera*), Vasambu (*Acorus calamus*), was conducted under laboratory conditions at the Department of Entomology, Adhiparasakthi Agricultural College, Kalavai, Ranipet during June to September, 2026. In the botanical treatment preference, fecundity and number of adults emerged was high in Thumbai (30.33 and 28.2) and low in Vasambu (4.0 and 2.33). Higher and lower percentage of adults was recorded in Thumbai and Vasambu (58.25 per cent) respectively. The percentage of weight loss was high on Thumbai (33.7 per cent) and low on Vasambu (6.0 per cent). Among the selected botanical treatments, the maximum oviposition period was recorded on Thumbai (30.33) and the minimum in Vasambu (4.0). The highest larval pupal period was noted on Thumbai and the lowest in Vasambu. The maximum longevity of the male was noted on Thumbai (7.33) respectively as against the minimum in Vasambu (4.66). The maximum longevity of female was noted on Thumbai (8.57) and minimum in Vasambu. With regard to the biology of the pulse beetle in certain pulses maximum life cycle was recorded on Thumbai and the minimum on Vasambu. Among the selected botanical treatments, the maximum per cent germination loss was recorded on Thumbai and the minimum per cent germination loss was recorded on Vasambu (73.3 per cent).

Keywords: Green gram, *Callosobruchus* sp., botanicals, preference, biology, quantitative losses.

PLANT TRAITS AS NATURAL DEFENSE: SCREENING OF COWPEA GENOTYPES AGAINST APHID INFESTATION

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Abstract

Cowpea (*Vigna unguiculata*) is a foremost important pulse crop for its protein rich grains, fodder and green pods. Nervertheless, it is hampered by various insect pests, among which the aphids, *Aphis craccivora* (Koch) are most predominant and also cause significant yield loss. Among the various management strategies, exploring and exploiting the resistance available in cowpea germplasm is an eco-friendly and effective approach to manage such insect pests. Also the physical and structural characteristics of cowpea may influence the aphid settling, movement and feeding. Considering the above, to observe the various biophysical characters in cowpea germplasm against *A. craccivora* five genotypes selected from preliminary evaluations were screened under field condition in the Department of Entomology, Faculty of Agriculture, Annamalai University, Annamalai nagar, Chidambaram, India. The results obtained from this study showed that, the height of the plant, leaf area, surface wax, leaf and pod wall thickness, length and breadth of the pod, angle between the pod and the peduncle length are recorded highest in the accession EC-724316 and contrast in EC-98442-II. Also in trichome evaluation study, highest number of trichomes was recorded in the resistant genotype in contrast with the susceptible one. The genotype EC-724316 were selected respectively for further evaluation against aphids and legume pod borer to develop desirable varieties.

Keywords: Cowpea, genotypes, aphids, biophysical characters, resistance.

ASSESSMENT OF IDM PRACTICES FOR GROUNDNUT SOIL BORNE DISEASE IN DHARMAPURI DISTRICT

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Abstract

Groundnut (*Arachis hypogaea* (L.)) is an important oilseeds in India with 4.7 million tonnes production from 4.7 million ha and is affected by soil-borne diseases. Soil-borne pathogens cause significant yield losses due to the close association of the groundnut pods with the soil. Effective management can enhance germination, reduce disease incidence, and improve pod yield. The experiment result carried out with two technologies and farmers practices. Among them Technology 1 (Seed treatment with carbendazim 2g/kg of seed Spray azoxystrobin 16.7 % + tricyclazole 33.3% SC @ 500 ml/ha after observing initial infection of the disease) demonstrated the highest yield of 23.50 q/ha and the highest net returns of Rs. 95,480/- with a B:C ratio of 2.90, followed by Technology 2 (Seed treatment at 2.0 g/kg seed with Carbendazim) also showed improved performance compared to the farmer's practice, with a yield of 22.25 q/ha and net returns of Rs. 88,350/-, achieving a B:C ratio of 2.78. The Farmer's Practice had the lowest yield of 18.00 q/ha, net returns of Rs. 63,860/-, and a B:C ratio of 2.32, indicating that while effective, it is less profitable compared to the newer technologies.

Keywords: Groundnut, oilseeds, soil borne, disease incidence

MICROBIAL CONSORTIA FOR MANAGEMENT SOIL BORNE DISEASES IN CHILLI

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Abstract

Chilli is one of the most valuable spice crop in is contributing about 40 % of the World's chilli. Several soil-borne diseases can affect chilli crops, which can effectively management is crucial to ensure healthy chilli plants and maximize yields. The experiment results revealed that, the two technologies and farmers practices were carried out in the farmers holdings. Among them Technology 1 (TNAU microbial consortia (*Bacillus subtilis, Trichoderma asperellum and Purpureocillium lilacinum*) - Seed treatment, soil application and root dipping @ 2.5kg/ha) demonstrated the highest yield of 210 q/ha and the highest net returns of Rs. 3,21,000/- with a B:C ratio of 3.68, followed by Technology 2 (Arka microbial consortium - Seed treatment @ 20 g / 100 g of seeds, soil application and root dipping 20 g / lit.) also showed improved performance compared to the farmer's practice, with a yield of 205 q/ha and net returns of Rs. 3,11,500/-, achieving a B:C ratio of 3.62. The Farmer's Practice had the lowest yield of 160 q/ha, net returns of Rs. 2,21,000/-, and a B:C ratio of 2.92, indicating that while effective, it is less profitable compared to the newer technologies.

Keywords: Chilli, spice crop, soil-borne, seed treatment, soil application, root dipping

APPLE POWDERY MILDEW: PATHOGEN BIOLOGY, EPIDEMIOLOGY AND STRATEGIES FOR SUSTAINABLE MANAGEMENT

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Abstract

Powdery mildew, caused by the obligate biotrophic ascomycete *Podosphaera leucotricha*, is one of the most important fungal diseases of apple (*Malus* × *domestica*) worldwide. The pathogen colonizes leaves, shoots, blossoms, and fruit, producing white powdery growth, stunted and distorted tissue, reduced photosynthesis, and russeted fruit. Together these effects cut yield and lower fruit quality. Unlike most other fungal pathogens, *P. leucotricha* does not need free water for infection, and it overwinters mainly as mycelium in dormant buds, which supplies primary inoculum each spring. Conidia spread by wind drive secondary infections throughout the season. This review summarizes current knowledge of the pathogen's biology, life cycle, and epidemiology, along with the environmental factors that favor disease. It also evaluates control measures, including sulfur and synthetic fungicides, pruning of infected shoots, biological control agents, and resistant cultivars. Fungicide programs are costly, require frequent applications, and carry a risk of resistance to site-specific modes of action. Breeding for resistance has used major resistance genes from wild *Malus* germplasm, but their durability against pathogen variation remains uncertain. Newer approaches, including marker-assisted selection and genome editing of susceptibility genes such as *MLO* homologs, offer routes to more durable resistance. Combining resistant cultivars, forecasting-based fungicide timing, sanitation, and biological control offers the most practical path to sustainable management.

Keywords: *Podosphaera leucotricha*, apple powdery mildew, *Malus* × *domestica*, disease epidemiology, fungicide resistance, host resistance, integrated management

ASSESSMENT OF GREENGRAM (*Vigna radiata* L.) VARIETIES UNDER IRRIGATED CONDITIONS IN PERAMBALUR DISTRICT, TAMIL NADU

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Abstract

Greengram (*Vigna radiata L.)* is an important pulse crop that contributes to nutritional security, soil fertility improvement and farm income. However, crop productivity is often constrained by yellow mosaic virus (YMV) disease, flower shedding and the continued cultivation of existing varieties. Varietal evaluation is therefore essential for identifying suitable high-yielding varieties under local farming conditions (Singh and Ahlawat, 2005). An on-farm technology assessment was conducted in five farmers' fields at Kurumbalur village, Perambalur district, Tamil Nadu, during the Rabi season to evaluate greengram varieties VBN 5 and CO 9 against the farmers' practice of cultivating VBN 2 under irrigated conditions. The assessment was conducted in sandy clay loam soil with a pH of 7.35. Among the varieties evaluated, VBN 5 recorded the highest grain yield of 7.43 q ha^{-1}, followed by CO 9 (7.05 q ha^{-1}) and VBN 2 (6.06 q ha^{-1}). VBN 5 registered a yield advantage of 22.61% over the farmers' practice. It also recorded the highest net return of ₹43,503 ha^{-1} and a benefit–cost ratio of 2.38, compared with ₹28,505 ha^{-1} and 1.98, respectively, under VBN 2. In addition, VBN 5 recorded the highest number of pods per plant and the lowest reported YMV incidence. The importance of evaluating yield-related traits and disease responses in greengram has also been highlighted in previous studies (Mohan et al., 2021; Naimuddin et al., 2016). The findings indicate that VBN 5 is a promising variety for improving greengram productivity and farm profitability under the assessed irrigated conditions in Perambalur district. Further evaluation across seasons and locations is recommended to confirm the consistency of its performance.

Keywords: Greengram, irrigated conditions, flower shedding, YMV incidence, farm, profitability

EFFICACY AND EVALUATION OF BIOLOGICAL METHODS FOR THE MANAGEMENT OF ROOT-KNOT NEMATODE *Meloidogyne incognita* IN TOMATO IN PERAMBALUR DISTRICT OF TAMIL NADU

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Abstract

Plant-parasitic nematodes are among the most important biotic stresses affecting the agricultural sector, causing annual economic losses of nearly USD 173 billion (Kantor et al., 2022). Root-knot nematodes (RKNs) pose a major threat to tomato growers, causing substantial losses in tomato production worldwide. As chemical Nematicides are expensive and harmful to human health and the environment, the present investigation was conducted to evaluate the efficacy of two biological management modules recommended by TNAU, Coimbatore, along with appropriate Integrated Crop Management (ICM) practices, for the management of *Meloidogyne incognita* in Tomato (*Solanum lycopersicum* L.) under field conditions. **Technology Assessed: Module 1 (M1):** Basal application of bio-enriched farmyard manure at 2.5 t/ha (*Purpureocillium lilacinum*), followed by the application of a liquid formulation of *P. lilacinum* at 2.5 L/ha through drip irrigation at the time of planting and repeated at 30, 60, and 90 days after planting. **Module 2 (M2):** Basal application of bio-enriched farmyard manure at 2.5 t/ha (*Pochonia chlamydosporia*), followed by the application of a liquid formulation of *P. chlamydosporia* at 2.5 L/ha through drip irrigation at the time of planting and repeated at 30, 60, and 90 days after planting. **Control:** Application of Carbofuran at 10 kg/ha. The results revealed that the adoption of biological management practices helped reduce nematode incidence in tomato. According to Jayakumar et al. (2023), the results indicated that biological management module M2 recorded the lowest nematode incidence of 6.75%, whereas it was 19.75% under control field, where chemical Nematicides were applied indiscriminately. The tomato yields recorded under M1 and M2 were 900.36 q/ha and 918.36 q/ha, respectively, representing increases of 24.30% and 21.90% over the yield under FP (738.50 q/ha). In terms of the benefit-cost (B) ratio, M2 achieved the highest ratio (2.46), followed by M1 (2.41), while the lowest ratio was observed under FP (1.85). This study clearly indicated that the adoption of biological management practices, with an emphasis on cultural practices, resulted in reduced RKN incidence and a reduction in the number of insecticide sprays, thereby lowering the cost

of cultivation and improving net income. The maximum net return was achieved under M2 (Rs. 272,834/ha), followed by M1 (Rs. 263,214/ha), while the minimum net return was recorded under FP (Rs. 165,780/ha).

Keywords: Tomato, *M. incognita*, *P. chlamydosporia*, *P. lilacinum*

MOLECULAR DETECTION OF BEGOMOVIRUS ASSOCIATED WITH PAPAYA LEAF CURL DISEASE USING UNIVERSAL PRIMERS

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Abstract

Papaya (*Carica papaya L.*) is an economically important fruit crop in tropical and subtropical regions, and its production is seriously constrained by papaya leaf curl disease (PaLCD). The disease is caused by begomoviruses (family Geminiviridae) and transmitted by the whiteflym Bemisia tabaci. Infected plants show upward and downward leaf curling, vein thickening, leaf distortion, stunted growth and reduced fruit yield. Because symptoms often resemble nutrient disorders or other viral infections, accurate diagnosis at the molecular level is essential. In the present study, we collected symptomatic papaya leaves showing typical leaf curl symptoms and maintained healthy leaves as a negative control. Total genomic DNA was extracted from the leaf tissue using a standard extraction protocol, and its quality was checked before amplification. Polymerase chain reaction (PCR) was then carried out with begomovirus universal primers, which are designed to target conserved regions of the begomovirus genome. We separated the amplified products by agarose gel electrophoresis, stained them, and visualised them on a gel documentation system alongside a DNA ladder for size estimation. Clear amplicons of the expected size were obtained from all symptomatic samples, while no amplification was observed in the healthy control. This confirmed the association of begomovirus with papaya leaf curl disease in the sampled plants. The results show that DNA extraction followed by PCR with universal primers is a rapid, sensitive and reliable method for detecting begomovirus in papaya. The findings can support early diagnosis, timely disease management and further studies on virus characterisation, including sequencing and phylogenetic analysis. Samples producing amplification products of the expected size will be considered presumptively positive for begomovirus DNA. Selected PCR products may subsequently be purified and sequenced to confirm the identity of the detected virus and assess its genetic relationship with previously reported begomovirus isolates. Sequence analysis and comparison with reference sequences available in public databases can provide additional information about viral diversity and possible genetic variation among isolates.

Since universal primers may differ in their ability to detect divergent viral strains, negative PCR results will be interpreted cautiously and, where necessary, followed by additional diagnostic assays.The expected outcome of this study is the establishment of a reliable molecular approach for detecting begomovirus associated with papaya leaf curl disease. The findings may support early disease diagnosis, surveillance of virus distribution, and future investigations into pathogen diversity and disease epidemiology. Overall, PCR-based detection using appropriately validated universal primers can serve as a useful preliminary diagnostic tool for papaya leaf curl-associated begomoviruses and contribute to improved disease monitoring and integrated disease management.

Keywords: Papaya leaf curl disease, Begomovirus, Universal primers, PCR, Gel electrophoresis, Molecular detection.

MUSHROOM SPENT SUBSTRATE AS AN ECO-FRIENDLY APPROACH FOR PLANT DISEASE MANAGEMENT

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Abstract

Spent mushroom substrate (SMS), a residual material generated during mushroom cultivation, is gaining attention as a sustainable resource for plant disease management and crop growth promotion. This review examines the potential of SMS and its aqueous extracts as eco-friendly alternatives to conventional disease-control approaches, focusing on antimicrobial activity, induced plant resistance and growth-promoting effects. Water extract of SMS (WESMS) derived from *Lentinula edodes* effectively suppressed *Phytophthora capsici*, the causal agent of pepper blight, reducing disease severity by 65% and enhancing plant growth by more than 30%. Oxalic acid was identified as a major organic acid associated with its antifungal activity. The treatment also enhanced the expression of defence-related genes and increased salicylic acid accumulation, suggesting the activation of host defence mechanisms. Similarly, SMS and aqueous extracts from *Lyophyllum decastes* and *Pleurotus eryngii* demonstrated protective effects against several cucumber diseases, including powdery mildew, scab, angular leaf spot and anthracnose. Furthermore, WESMS derived from *Hericium erinaceus* exhibited antibacterial activity against phytopathogens and reduced bacterial wilt caused by *Ralstonia solanacearum* in tomato seedlings by 85%, alongside improvements in plant growth and the expression of defence-associated genes. SMS from different mushroom species has also shown potential for suppressing basal rot of shallot caused by *Fusarium oxysporum* f. sp. *cepae*. Collectively, these findings indicate that SMS may contribute to integrated plant disease management through direct pathogen inhibition, activation of plant defence responses and crop growth promotion. Its agricultural utilisation also offers an opportunity to recycle mushroom-industry residues and support circular bioeconomy principles. However, further research is required to standardise extraction procedures, identify bioactive compounds, optimise

application rates and validate efficacy under field conditions. Thus, SMS represents a promising resource for developing sustainable, low-input plant disease management strategies.

Keywords: Spent mushroom substrate; aqueous extract; plant disease management; antimicrobial activity; induced resistance; sustainable agriculture.

HARNESSING *Pseudomonas fluorescens* FOR SUSTAINABLE MANAGEMENT OF RICE SHEATH BLIGHT CAUSED BY *Rhizoctonia solani*

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Abstract

Rice (*Oryza sativa* L.) is an important staple food crop in India and serves as a major source of food for a large population. Among the several diseases affecting rice production, sheath blight, caused by *Rhizoctonia solani*, is one of the most destructive diseases and can result in considerable yield reduction. The extensive use of chemical fungicides for disease control may lead to environmental pollution and adversely affect soil, water and agricultural ecosystems. Therefore, the use of beneficial microorganisms offers an environmentally safe and sustainable alternative for managing plant diseases. In this study, the antagonistic potential of ten *Pseudomonas fluorescens* isolates (Pf_1 to Pf_{10}) obtained from the rhizosphere soil of rice plants, was evaluated against *R. solani* under *in-vitro* conditions at the Department of Plant Pathology, Faculty of Agriculture, Annamalai University, Chidambaram, India. The isolates were assessed for their ability to suppress mycelial growth and sclerotial formation using dual culture and poison food techniques. Among the tested isolates, Pf_5 demonstrated the highest antagonistic activity against *R. solani*. Its influence on rice seedling growth was further evaluated through a roll towel experiment. Pf_5 recorded maximum seed germination (95.70%), shoot length (10.64 cm), root length (9.26 cm), and vigour index (1904.43). The findings indicate that the *Pseudomonas fluorescens* isolates Pf_5 possesses considerable potential as a biological control agent against rice sheath blight while promoting early plant growth.

Keywords: Sheath blight, Antagonist, Dual culture, Poisoned food technique, Roll towel, Sustainable management.

TEMPORAL PATTERNS AND COMMUNITY STRUCTURE OF FLORAL VISITORS IN SNAKE GOURD (*Trichosanthes cucumerina* L.) IN COIMBATORE, TAMIL NADU

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Abstract

Floral visitors play an important role in the reproductive ecology of flowering plants and may contribute to pollination and ecosystem functioning. The present study was conducted at Narasipuram, Coimbatore district, Tamil Nadu, India (10.998716° N and 76.800541° E), to document the diversity, species richness, evenness and temporal distribution of floral visitors associated with the snake gourd (*Trichosanthes cucumerina* L.) ecosystem. A total of nine species belonging to four families and three insect orders were recorded from snake gourd flowers. Lepidoptera was the most species-rich order, comprising six species: *Papilio hector*, *Pachliopta aristolochiae*, *Delias eucharis*, *Pareronia hippie*, *Catopsilia* sp. and *Anthocharis cardamines*, representing the families Papilionidae and Pieridae. Coleoptera was represented by two species, *Aulacophora cincta* and *Acalymma* sp., belonging to the family Chrysomelidae, while Hymenoptera was represented by a single species, *Tetragonula iridipennis*. Temporal variations in the floral visitor community were assessed using Simpson's diversity index, Shannon's diversity index, Margalef's species richness index and Pielou's evenness index. Simpson's diversity index ranged from 0.20 to 0.57, whereas Shannon's diversity index varied from 0.69 to 1.75. The highest floral visitor diversity and species richness were recorded between 0900 and 1000 h, indicating this period as a prominent time of floral visitor activity. In contrast, maximum species evenness was observed between 0600 and 0700 h, suggesting a more uniform distribution of individuals among the recorded species during the early morning hours. Day-wise analysis further revealed comparatively higher diversity, species richness and evenness on the second and ninth days of observation. These findings demonstrate that the floral visitor assemblage associated with snake gourd exhibits variation in species composition and community structure across observation periods, with lepidopterans contributing the

greatest species richness. The study provides baseline information on the diversity and temporal patterns of floral visitors in the snake gourd ecosystem and highlights the importance of considering the timing of floral visitor activity in ecological monitoring and the conservation of beneficial insects in cucurbit cultivation.

Keywords: Snake gourd, floral visitors, insect diversity, species richness, Shannon diversity index, Simpson's diversity index, species evenness, temporal distribution.

GENETIC, MORPHOLOGICAL, AND BIOCHEMICAL MECHANISMS OF INSECT PEST RESISTANCE IN OKRA (*Abelmoschus esculentus* L.)

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Abstract

Okra (*Abelmoschus esculentus L.)* is an economically important vegetable crop widely cultivated in tropical and subtropical regions. However, insect pests, particularly the shoot and fruit borer (Earias vittella), aphids, jassids, and whiteflies, affect its growth and yield. Developing insect-resistant okra varieties offers a sustainable alternative to heavy reliance on chemical insecticides. Okra possesses diverse genetic, morphological, biochemical, and molecular defence mechanisms that help reduce insect damage. Morphological traits such as high trichome density, longer trichomes, thicker fruit pericarp, and tougher plant tissues can influence insect feeding and oviposition. Biochemical defences, including phenolics, tannins, flavonoids, proteinase inhibitors, and other secondary metabolites, contribute to reducing insect growth and survival. At the molecular level, defence responses are regulated through signalling pathways involving jasmonic acid, salicylic acid, and ethylene, which activate defence-related genes during insect attack. Genetic variability among okra genotypes provides valuable resources for identifying resistance-associated traits through conventional breeding, mutation breeding, molecular breeding, genomic selection, and genome-editing approaches. Furthermore, advances in transcriptomics, metabolomics, and functional genomics have improved our understanding of plant–insect interactions and the molecular basis of resistance in okra. Integrating genetic resistance with biological control and Integrated Pest Management (IPM) offers a promising strategy for reducing pesticide use while enhancing crop productivity and environmental sustainability. This review summarizes the genetic and molecular mechanisms underlying insect resistance in okra and highlights their applications in developing resilient varieties for sustainable crop protection.

Keywords: Okra, Jasmonic acid, molecular breeding, sustainable crop protection.

OCCURRENCE AND MOLECULAR DIAGNOSIS OF PHYLLODY DISEASE IN PULSES IN TAMIL NADU

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Abstract

Phyllody disease associated with phytoplasma has emerged as a significant constraint in pulse production in Tamil Nadu, affecting blackgram (*Vigna mungo*), greengram (*Vigna radiata*) and redgram (*Cajanus cajan*). The disease causes severe morphological abnormalities, adversely affecting normal plant growth, floral development and reproductive potential. A systematic survey was conducted in major pulse-growing regions of Tamil Nadu during 2022–2025 across different cropping seasons to assess the occurrence of phyllody disease and investigate the associated phytoplasma through molecular diagnostic techniques. The survey revealed the occurrence of phyllody disease in all the seasons examined, with the maximum incidence recorded during the Kharif 2024 season. The highest incidence was observed in blackgram in Pudukkottai district, while greengram and redgram showed maximum incidence in Coimbatore district, indicating variation in disease occurrence among pulse crops and geographical locations. The characteristic symptoms observed in infected plants included phyllody, virescence, leaf yellowing, reduced leaf size, stunted growth, witches' broom, leaf curling and bunchy growth at the stem terminals. Additional symptoms included floral gigantism, twig die-back and premature yellowing or reddening of leaves, accompanied by general plant decline. These abnormalities indicated substantial disruption of normal vegetative and reproductive development. Since phytoplasmas are wall-less, phloem-associated microorganisms that are difficult to culture under artificial in vitro conditions, molecular diagnosis was employed to confirm their association with the disease. Nested polymerase chain reaction (Nested PCR) was used as a rapid and sensitive diagnostic approach for detecting phytoplasma in symptomatic plant samples. The second-round amplification using specific primers targeting the 16S ribosomal RNA gene region facilitated the detection of phytoplasma-associated infection in blackgram, greengram and redgram samples.

Molecular analysis followed by nucleotide sequence comparison revealed more than 99% sequence similarity between the phytoplasma isolates associated with the three pulse crops and reference isolates of *'Candidatus Phytoplasma aurantifolia'* available in the National Centre for Biotechnology Information (NCBI) database. These findings supported the association of the detected phytoplasma with the 16SrII group, commonly referred to as the Peanut witches' broom group. The study highlights the importance of systematic disease surveillance and molecular confirmation for the reliable diagnosis of phytoplasma associated phyllody in pulses. Nested PCR and sequence analysis provide useful tools for identifying the associated pathogen and supporting further epidemiological investigations. The findings also emphasize the need for continued monitoring of disease incidence across seasons and locations, together with studies on vector-mediated transmission and integrated disease management, to minimize potential losses in pulse production in Tamil Nadu.

Keywords: Blackgram, greengram, redgram, phyllody, phytoplasma, Nested PCR, *'Candidatus Phytoplasma aurantifolia'*, 16SrII group.

EVALUATION OF *Ampelomyces quisqualis* FOR THE BIOLOGICAL MANAGEMENT OF POWDERY MILDEW IN BLACKGRAM (*Vigna mungo* L.)

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Abstract

Powdery mildew, caused by fungal pathogens, is an important disease affecting blackgram (*Vigna mungo* L.) and can adversely influence crop growth and productivity. The extensive use of chemical fungicides for disease management raises concerns regarding environmental contamination, ecological imbalance and potential risks to human health through the food chain. Consequently, biological control has gained considerable attention as an eco-friendly component of integrated disease management. *Ampelomyces quisqualis*, a naturally occurring mycoparasite of powdery mildew fungi, offers considerable potential for suppressing disease development through direct parasitism of the pathogen. It colonizes the hyphae, conidiophores and chasmothecia of powdery mildew fungi and produces pycnidia within infected fungal structures. During mycoparasitism, the interaction initially involves the invasion of the host fungal cells, followed by degeneration of the invaded cytoplasm and disruption of pathogen development. This process can reduce sporulation and limit the spread of powdery mildew.

The present investigation evaluated the mycoparasitic potential of *A. quisqualis* against powdery mildew in blackgram under pot culture and field experimental conditions. The pot culture experiment demonstrated that foliar application of a 0.5% liquid formulation of *A. quisqualis* resulted in a maximum reported reduction in powdery mildew disease of 16.76%. Further evaluation was conducted using pooled experimental data collected during 2022-2024 to determine the effectiveness of the biocontrol agent under field conditions. The results indicated that foliar application of a 5% liquid formulation of *A. quisqualis* at the initial appearance of disease symptoms, followed by a second application 10 days later, was the most effective treatment among those evaluated. This treatment recorded the lowest powdery mildew disease intensity of 28.50%, a seed yield of 813 kg ha^{-1} and a benefit–cost ratio of 1.98. The

findings demonstrated the potential of *A. quisqualis* to reduce disease intensity while maintaining satisfactory crop productivity and economic returns.

The results emphasize the importance of timely application of the mycoparasite, particularly during the early stages of disease development, to achieve effective suppression of powdery mildew. Although biological suppression may develop more slowly than the action of conventional fungicides, the ability of *A. quisqualis* to parasitize powdery mildew fungi makes it a promising candidate for environmentally compatible disease management. The observed reduction in disease intensity and favourable economic performance suggest that its use could be integrated into broader disease management programmes for blackgram. Further studies on formulation stability, application timing, environmental influences and compatibility with other integrated disease management practices would help improve its practical utility. Overall, *A. quisqualis* represents a promising biological control option for managing powdery mildew in blackgram and reducing dependence on chemical fungicides.

Keywords: *Ampelomyces quisqualis*, blackgram, biological control, mycoparasitism, powdery mildew, disease suppression.

THE SWEET SWITCH: REPROGRAMMING PLANT SUSCEPTIBILITY INTO RESISTANCE

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Abstract

Using chemical fungicides, bactericides in plant disease management may offer quick fixes, but it disrupts nature and also fuels the rise of resistant pathogens, turning minor issues into major threats. This study examines the interplay between sweet genes and disease resistance, which is recently recognized as a key factor in ensuring the sustainable agriculture and disease management. Sweet genes are genes, located in the plasma membrane, which encode sweet proteins that transports sugar in one direction across the cell membrane in plants. These sugar transporters are often function as Susceptibility genes and often hijacked by pathogens for the supply of sugar as a source of nutrition for themselves. Pathogens like *Xanthomonas* can upregulate SWEET gene expression through transcription activator-like effectors (TALES), enhancing their virulence. However, Binding of TALES from pathogen and Electron Binding Element (EBE) from Sweet Promoter of host plant is the reason for virulence infection. Therefore, in order to develop disease resistance, alteration in the binding site should be done. This can be achieved by important genetic approaches like CRISPR /Cas9 Genome editing, TALEN Mediated editing, Cloning of Executor Genes. The ultimate objective of this study is to develop disease- resistant cultivars on various crops in future plant breeding programmes "Sustainability meets immunity in agriculture".

Keywords: Genome Engineering, TALES, plant-microbe interactions, Sweet Genes, *Xanthomonas.*

BENEFICIAL INSECTS AND THEIR ROLE IN SUSTAINABLE PEST MANAGEMENT

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Abstract

Insects play diverse roles in agroecosystems, functioning both as destructive pests and as beneficial allies. While insect pests cause significant yield losses and economic damage, beneficial insects contribute to ecological balance and agricultural productivity through predation, parasitism, pollination, and nutrient cycling. This study highlights the ecological and economic importance of beneficial insects such as lady beetles, lacewings, weaver ants, tachinid flies, and honey bees. These organisms regulate pest populations naturally, reducing dependence on chemical pesticides and supporting Integrated Pest Management (IPM) strategies. Beyond pest suppression, beneficial insects enhance soil fertility through decomposition, aid in weed management, and provide essential pollination services critical for crop reproduction. Furthermore, they contribute to commercial products including honey, silk, shellac, and natural dyes, underscoring their multifaceted value. Recognizing and conserving beneficial insect diversity is vital for sustainable agriculture, biodiversity conservation, and food security. This work emphasizes the need for farmer awareness, ecological monitoring, and policy support to integrate beneficial insects into pest management programs, thereby promoting environmentally sound and economically viable farming systems.

Keywords: Beneficial insects, insect pests, predation, pollination, integrated pest management, sustainable agriculture

Trichoderma AS A BIOCONTROL AGENT FOR SUSTAINABLE PLANT DISEASE MANAGEMENT

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Abstract

The biocontrol activity of *Trichoderma* involves several mechanisms, including mycoparasitism, antibiosis, competition for nutrients and space, and the production of cell-wall-degrading enzymes such as chitinases, glucanases, and proteases. These mechanisms help suppress pathogen growth and reduce disease incidence. Furthermore, *Trichoderma* can induce systemic resistance in plants by activating their natural defence mechanisms, thereby enhancing tolerance against pathogen attack. Certain strains also promote plant growth by improving nutrient availability, stimulating root development, and enhancing nutrient uptake.

The effectiveness of *Trichoderma* depends on the fungal species and strain, environmental conditions, soil properties, crop type, and pathogen characteristics. Commonly studied species, such as *Trichoderma harzianum, T. viride,* and *T. asperellum*, have demonstrated potential for controlling several economically important plant diseases. These beneficial fungi can be applied through seed treatment, seedling root dipping, soil application, and integration with organic amendments. Combining *Trichoderma* with other compatible biological control agents and cultural practices may further improve disease suppression and crop productivity.

Despite its advantages, certain challenges, including inconsistent field performance, sensitivity to environmental conditions, formulation stability, and compatibility with agrochemicals, can limit its effectiveness. Therefore, further research on strain selection, molecular characterization, formulation development, and field-level validation is essential for improving its practical application.

In conclusion, *Trichoderma* represents a promising component of integrated plant disease management because of its multiple biocontrol mechanisms, plant growth-promoting properties, and environmental benefits. Its effective utilization can reduce dependence on synthetic pesticides, improve soil health, and support sustainable crop production. The integration of Trichoderma-based formulations into modern agricultural practices offers

considerable potential for developing resilient, productive, and environmentally sustainable farming systems.

Keywords: *Trichoderma*, biological control, plant pathogens, sustainable agriculture, integrated disease management, plant growth promotion.

ASSESSMENT OF GENETIC VARIABILITY PARAMETERS FOR YIELD AND ITS COMPONENTS IN CHICKPEA (*Cicer arietinum* L.)

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Abstract

The present experiment was carried out at Crop research Centre II of the Genetics and Plant breeding, school of Agriculture ITM University, Gwalior, M.P, to study the genetic variability, Heritability, Genetic advance, correlation analysis in Fifteen germplasm of chickpea during rabi 2021-22. The objective of present study was to estimate magnitude of different parameters of genetic variability for yield and its attributes. The maximum phenotypic coefficient of variation (PCV) and genotypic coffecient of variation (GCV) were notice for –seed weight, Total yield per plot, grain yield per plant and number of seeds per pod. High heritability was recorded by 100 seed weight, total yield per plot, primary branches per plant, grain yield per plant, total number of pods per plant, secondary branches per plant, plant height, days to 50% flowering and days to maturity. High heritability coupled with high genetic advance as percent of mean was observed for total yield per plot, primary branches per plant, grain yield per plant, total number of pods per plant, secondary branches per plant and plant height which suggested that these characters can be considered as favorable attributes for the improvement through selection. It is revealed the presence of additive gene effect for these characters. So, the utmost importance should be given to these characters during the selection for yield improvement in chickpea. Traits such as plant height, Number of secondary branches, no of seeds per pod, 100 seed weight, exhibited significant positive correlation with grain yield per plant and this will show greater direct effect on single yield plant.

Keywords: *Cicer arietinum L.;* genetic variability; correlation; heritability, genetic advance and grain yield.

RNA-BASED BIOPESTICIDES: A NEW ERA OF PRECISION PLANT PROTECTION

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Abstract

The demand for reliable and sustainable crop protection techniques has been increasing as the incidence of resistance to pesticides, pesticide pollution, and off-target effects of conventional pesticides has increased. Through RNA interference (RNAi), a natural process that regulates the expression of genes, RNA-based biopesticides have emerged as a promising alternative. Double-stranded RNA (dsRNA) molecules that aim to disrupt the function of key genes in the target insect pests or genes involved in the pathogen invasion and development are the primary tools in RNA technology. The RNAi system converts the dsRNA into short interfering RNAs upon cellular uptake of the latter. The RNAs guide the sequence-specific breakdown of the complementary messenger RNA, thus downregulating the expression of the target gene. RNA-based crop protection can be achieved through topical application, plant-mediated processes, or other RNA delivery mechanisms, depending on the target organism and delivery mode. Spray-induced gene silencing offers a promising means for developing externally applied, sequence-specific crop protection products without necessarily genetically modifying the plant in question. Nevertheless, the limitations of RNA technology as an approach to crop protection include high delivery costs, variability in efficacy, poor absorption by some target organisms, instability of RNA molecules under field conditions, and need for environmental risk assessment. The selection of target genes, RNA formulations, protective vehicles, and delivery technologies may improve the biological efficiency and stability. Sustainable agricultural output and reduced dependence on conventional chemical pesticides may be possible through the combination of RNA-based biopesticides with biological control, plant tolerance, and integrated pest management. Further studies, field testing, and regulation will be required in order to turn this novel technology into efficient and economically feasible crop protection solutions.

Keywords: RNA interference, double-stranded RNA, RNA-based biopesticides, spray-induced gene silencing, precision pest management, sustainable crop protection.

RESILIENCE STRATEGIES FOR SUSTAINABLE AGRICULTURE, CROP HEALTH AND PLANT PROTECTION

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Abstract

Agricultural systems worldwide are under growing pressure from climate variability, the spread of emerging and transboundary pests and pathogens, soil and water degradation, and the need to feed an expanding population with fewer external inputs. Heavy reliance on synthetic agrochemicals and genetically narrow cropping systems has delivered short-term productivity gains but has also increased vulnerability to pest outbreaks, resistance evolution, and environmental harm. Building resilience, the capacity of agroecosystems to resist, absorb, and recover from biotic and abiotic stresses, has therefore become central to sustaining yields, protecting crop health, and securing farmer livelihoods. This paper reviews and synthesizes strategies for strengthening resilience in crop production and plant protection.

We organize the evidence across three interconnected levels. At the crop level, we examine breeding and deployment of durable disease-resistant and climate-tolerant varieties, the value of genetic diversification within and across fields, and the use of beneficial microbes, bio-stimulants, and induced resistance to enhance plant immunity and stress tolerance. At the field level, we assess integrated pest management, biological control, crop rotation, intercropping, cover cropping, and conservation tillage, together with the judicious and rotational use of chemical inputs to slow resistance development and limit non-target effects. At the system level, we consider digital and precision technologies, including remote sensing, AI-based disease detection, decision-support tools, and early-warning and surveillance networks, alongside the enabling roles of policy, extension services, farmer knowledge networks, and market incentives in driving adoption.

The synthesis shows that no single measure delivers durable protection. Resilience emerges from combining diverse, complementary practices tailored to local agroecological and socio-economic conditions. Genetic resistance is most durable when paired with agronomic diversity, and biological and cultural controls are most effective when supported by timely monitoring and informed decision-making. Digital tools can sharpen the timing and targeting of

interventions, but their benefits depend on data quality, local validation, and accessibility to end users.

Important gaps remain. Proven technologies are often not scaled to smallholder systems because of cost, infrastructure, and knowledge barriers. Long-term trade-offs among productivity, environmental sustainability, and economic viability are poorly quantified. Coordinated international surveillance of transboundary threats, and standardized, open data sharing, remain limited. Future work should prioritize participatory research with farmers, field-scale validation of emerging technologies, and policy frameworks that reward ecosystem services and risk reduction. We conclude that integrating ecological, technological, and socio-economic approaches offers the most promising pathway to sustainable crop protection and food security under changing environmental conditions.

Keywords: crop resilience; sustainable agriculture; plant protection; integrated pest management; climate adaptation; plant disease management; precision agriculture

PLANT RESISTANCE TO EMERGING DISEASES

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Abstract

The emergence and spread of plant diseases threaten crop productivity, food security, and the stability of agricultural livelihoods. New pathogen strains, changing climate conditions, global movement of plant material, and intensive production systems can alter disease risks and overcome resistance in widely grown cultivars. This article reviews how plant resistance can be developed and deployed as part of a durable strategy for managing emerging diseases. It focuses on the interaction between host plants, pathogens, and the environments in which disease develops. Examples include late blight caused by *Phytophthora infestans* in potato, rice blast caused by *Magnaporthe oryzae*, and bacterial blight caused by *Xanthomonas oryzae* pv. *oryzae* in rice. Resistance can arise from major genes that recognize particular pathogen effectors, from multiple genes that provide partial but often more durable protection, or from combinations of both. Advances in genomic sequencing, marker-assisted breeding, genomic selection, and gene editing are expanding opportunities to identify useful resistance traits and introduce them into locally adapted crops. However, resistance is not permanent: pathogen populations can evolve, and a resistance source used widely on its own may lose effectiveness. Breeding programs can reduce this vulnerability by combining resistance genes, using diverse genetic resources, and testing candidate varieties across locations and seasons. Field surveillance and accurate disease diagnosis are also essential for detecting new pathogen variants and tracking changes in virulence. Integrating resistant cultivars with crop rotation, clean planting material, balanced nutrient management, biological control, and other locally appropriate practices can further reduce disease pressure and slow pathogen adaptation. Effective deployment depends on collaboration among plant pathologists, breeders, extension specialists, and farmers. The article concludes that sustained investment in resistance research, pathogen monitoring, and diverse crop systems is necessary to protect harvests while limiting avoidable dependence on chemical control. These measures can strengthen agricultural resilience as disease threats continue to change.

Keywords: Plant resistance; emerging plant diseases; host–pathogen interaction; disease-resistant cultivars; plant breeding; pathogen surveillance; integrated disease management.

SOIL HEALTH AND CONSERVATION PRACTICES FOR CLIMATE RESILIENCE

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Abstract

Healthy soils support crop production, regulate water, store carbon, and sustain diverse organisms, making soil conservation central to climate-resilient agriculture. This article reviews practices that maintain or improve soil health while helping farms withstand drought, intense rainfall, heat, and other climate stresses. Cover crops, crop rotations, reduced tillage, residue retention, contour cultivation, and agroforestry can protect soil from erosion, increase organic matter, and improve water infiltration. These benefits may strengthen soil structure and help crops access moisture during dry periods, while reducing runoff during heavy rain. Integrating organic amendments and balanced nutrient management can support nutrient cycling and reduce losses to the environment. Soil biodiversity also contributes to resilience; beneficial organisms such as *Rhizobium leguminosarum* and arbuscular mycorrhizal fungi such as *Rhizophagus irregularis* can assist nutrient acquisition in suitable crop systems. However, outcomes depend on local climate, soil type, crop choice, and management, so conservation practices should be adapted and assessed over time. The article emphasizes combining complementary measures rather than relying on a single intervention. Farmer knowledge, soil testing, extension support, and long-term monitoring can guide practical decisions and track changes in soil condition. By conserving soil resources and improving their capacity to retain water and nutrients, resilient management can reduce production risks, support ecosystem functions, and contribute to sustainable agricultural systems under a changing climate.

Keywords: soil health; soil conservation; climate resilience; cover crops; reduced tillage; soil organic matter; water management; sustainable agriculture

SEASONAL INCIDENCE OF DISEASES OF MARIGOLD (*Tagetes sp*.) IN GUDLUPETE, KARNATAKA

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Abstract

Marigold (*Tegetes sp*.) is a commercially important flower crop in Gudlupete, Chamarajanagar district, Karnataka, where it is widely grown for loose flowers, garlands and for its pigment, Xanthophyll. Diseases are a major constraint on productivity and flower quality, and their incidence varies with weather. A study was conducted to assess the seasonal incidence of marigold diseases in Gudlupete during the Kharif (monsoon), winter and summer seasons of 2024 August to 2026 April. Fixed plots were surveyed at fortnightly intervals, and disease incidence and severity were recorded using a 0-5/0-9 rating scale and converted to percent disease index (PDI). Weather parameters, namely temperature, relative humidity, rainfall and rainy days, were collected weekly, and their relationship with disease progress was analysed using correlation and regression.

The major diseases observed were *Septoria* leaf spot, *Alternaria* leaf blight, *Fusarium* wilt (*Fusarium oxysporum*) and *Botrytis* flower blight and major pests observed were Thrips, *Helianthus* larva, Mites. Foliar diseases were most severe during the kharif season, with a maximum PDI of 57%, when frequent rainfall, high humidity **(>90%)** and moderate temperatures (20-28 °C) favoured infection. Wilt incidence was highest in summer, it is associated with higher soil temperatures and moisture stress. Correlation analysis showed a significant positive association of leaf spot and blight severity with relative humidity and rainfall.The findings give a clear picture of the seasonal disease dynamics of marigold in Gudlupete. They can help growers and extension workers time preventive sprays, adjust irrigation and spacing, and develop a weather-based forewarning system for integrated disease management.

Keywords: Marigold, seasonal incidence, percent disease index, weather parameters, Gudlupete.

CRISPR-CAS GENOME EDITING AS AN EMERGING TOOL FOR SUSTAINABLE CROP PROTECTION

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Abstract

Consequences of global warming, increasing incidence of plant pathogens, insects and high costs associated with intensive use of pesticides create threats for crop production. Although conventional breeding remains crucial in developing resistance against different biotic and abiotic stresses, the limitation can include availability of genetic variability, linkage drag and time needed for accumulating the desired trait combinations. In recent years, CRISPR-Cas genome editing has become an accurate and flexible method for making modifications of selected DNA sequences and crop improvement. This abstract considers the possibilities for using this technology in sustainable crop protection, focusing on disease resistance. CRISPR-Cas9 system involves guide RNA that binds to Cas9 nuclease and directs it to the genomic sequence complementary to the guide RNA. Cas9 cuts the targeted sequence, and plant cell makes the necessary repair, creating mutations or, when a repair template is provided, desire modifications of the DNA sequence. The researchers can create resistance by editing genes that increase susceptibility to pathogens, modifying defense-related genes or by enhancing the activity of certain resistance genes. Genome editing technologies have been applied to many crops, such as rice, wheat, maize, potato and cassava, to develop resistance to viral, bacterial and fungal pathogens. There are some novel approaches to genome editing, such as base editing and prime editing that enable selected nucleotide changes with minimal off targets. One of the strengths of the CRISPR-Cas technology is the ability to modify the existing genes in the crop genomes. If used properly, this can facilitate traditional selection and breeding. Disease-resistant cultivars can reduce losses during crop production and, in appropriate production system, decrease applications of pesticides. Thus, there can be benefits for the environment and crop protection efficiency. Multiplex editing enables modification of several genes involved in plant defense, facilitating breeders work related to complicated disease resistance processes. However,the results largely depend on the genotype of the crop, biology of the pathogen, function of the selected gene and durability of the resistance. There are several obstacles to be solved for the widespread application of this technology in breeding programs. Off-target edits,

unexpected effects on growth and yield, problems with transformation and regeneration, lack of relevant genomic data, evolution of pathogens and others can limit research. Edited resistance should be tested against diverse pathogen populations and, when possible, used together with other resistance sources and disease management techniques. Performance in the field, food safety, environmental safety, public opinion, issues of intellectual property and national legislation should be carefully considered. Therefore,CRISPR-Cas technology should be viewed as a complement to conventional breeding and disease protection practices. To conclude, CRISPR- Cas genome editing is a promising approach to the crop improvement and creation of resistant cultivars. This technology has great potential when applied together with plant pathology, molecular genetics, breeding and field testing of crops. It can contribute to more sustainable agricultural systems and reduction of unnecessary dependence on pesticides. In order to achieve positive results, it is necessary to identify and validate targets, to ensure durability of resistance and proper regulation.

Keywords: CRISPR-Cas9; gene editing; disease resistance; crop improvement; sustainable crop protection; plant breeding

IMPROVEMENT OF SEEDLING ESTABLISHMENT AND DEFENSE RESPONSES IN RICE THROUGH PGPR-BASED SEED PRIMING

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Abstract

Seed priming with plant growth-promoting rhizobacteria (PGPR) has emerged as a sustainable strategy to enhance seed germination, seedling vigour, and early plant development.This study investigated the effects of various antagonistic bacterial isolates on germination parameters, seedling growth, and defense-related enzyme activity in rice (Oryza sativa). Seeds were treated with bacterial isolates at 1 ml and 2 ml concentrations, and their impact on germination percentage, seedling length, vigour index, total dry matter production (TDMP), and activities of phenylalanine ammonia-lyase (PAL), polyphenol oxidase (PPO), and peroxidase (PO) was assessed. Among the tested isolates, AM1 and KA3 significantly improved seedling growth and vigour. AM1 showed the highest total dry matter accumulation and vigour indices, while KA3 at 2 ml concentration induced the maximum levels of defense enzyme activity, indicating enhanced systemic resistance. The results suggest that these bacterial isolates, particularly AM1 and KA3, have strong potential as bio-inoculants to promote early growth and disease resistance in rice, offering an eco-friendly alternative to chemical treatments.

Keywords: Plant growth-promoting rhizobacteria (PGPR), rice, antagonistic bacteria, seedling vigour, plant growth promotion, defense-related enzymes.

IMPACT OF RHIZOCTONIA SOLANI ISOLATES ON RICE SHEATH BLIGHT INCIDENCE

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Abstract

Sheath blight of rice, caused by Rhizoctonia solani Kühn, is a destructive fungaldisease that significantly impacts rice productivity across major rice-growing regions of Tamil Nadu. A comprehensive field survey was carried out across the primary rice-producing regions of Tamil Nadu with the highest severity recorded in areas exhibiting conducive environmental conditions. Samples were gathered from four districts viz., Chengalpattu (Rs 1, Rs 2, Rs 3, Rs 4, Rs 6), Cuddalore (Rs 5), Thanjavur (Rs 7), and Theni (Rs 8, Rs 9, Rs 10).Ten isolates of R. solani collected from different locations in Tamil Nadu were isolated and characterized based on their cultural, morphological, and pathogenic variability. Among the isolates evaluated, Rs6 collected from Orathy was identified as the most virulent isolate. Morphological characterization confirmed typical hyphal structures of R. solani, while molecular identification using ITS sequencing validated the pathogen. Forty native rhizosphere bacterial isolates belonging to Bacillus spp. were screened for their antagonistic potential against the pathogen. Among the promising isolates, KA3, identified as Bacillus amyloliquefaciens, exhibited superior antagonistic activity and was further evaluated for plant growth-promoting traits, compatibility with fungicides, and its role in disease suppression.

Keywords: Rice sheath blight, isolates of Rhizoctonia solani, KA3 Bacillus amyloliquefaciens, biological control.

BREAKING THE RESISTANCE CODE: SYNERGISTS AS GAME-CHANGERS IN INSECTICIDE RESISTANCE MANAGEMENT

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Abstract

Insecticide resistance has emerged as a major challenge to sustainable crop protection and vector management, threatening agricultural productivity and the effectiveness of public health interventions. The repeated and indiscriminate use of insecticides has accelerated the evolution of resistance in insect populations through diverse mechanisms, including target- site insensitivity, enhanced metabolic detoxification, reduced cuticular penetration and behavioural avoidance. Among these mechanisms, metabolic resistance mediated by cytochrome P450 monooxygenases, carboxylesterases and glutathione S-transferases (GSTs) represents an important target for resistance management. In this context, insecticide synergists offer a promising approach to improving insecticide efficacy by suppressing specific detoxification pathways and enhancing the toxicity of selected insecticides. Synergists are compounds that increase the biological activity of insecticide when used in combination, often by interfering with the insect's capacity to metabolise or detoxify the active ingredient. Piperonyl butoxide (PBO) a widely studied synergist, primarily inhibits cytochrome P450-mediated metabolism, whereas S,S,S-tributyl phosphorotrithioate (DEF) and diethyl maleate (DEM) are commonly employed in experimental studies to investigate esterase- and GST-associated detoxification, respectively. Synergism bioassays, together with biochemical and molecular analyses, can help identify the contribution of metabolic enzymes to resistance and distinguish metabolic resistance from other mechanisms. Recent studies have demonstrated that synergists can substantially suppress resistance in certain insect populations; however, their effectiveness varies according to insect species, insecticide class,resistance mechanism and the presence of multiple resistance mechanisms. Despite their potential, synergists are not universal solutions. Target-site mutations, reduced insecticide penetration, alternative detoxification pathways and physiological adaptations may limit their effectiveness. Moreover, repeated exposure to synergist–insecticide combinations may select for additional resistance mechanisms, while formulation compatibility, environmental persistence, non-target effects, regulatory

considerations and economic feasibility require careful evaluation. Therefore, synergists should be integrated into broader insecticide resistance management programmes rather than used as stand-alone solutions. Future research should prioritise novel and environmentally compatible synergists, mechanistic validation, resistance surveillance and integration with insecticide rotation, biological control and other integrated pest management strategies. A mechanism-based approach to synergist use can help preserve insecticide efficacy and support more sustainable pest management.

Keywords: Detoxifications, insecticide resistance, integrated pest management, synergist effect, resistance mechanisms.

REFRESHERS – A NEW ERA IN INSECTICIDE

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Abstract

Humans use a lot of chemicals in their day today life including room refreshers. It comes in many flavours such as lemon, orange, lavender, jasmine and rose are common. The price and the strongness varies with each company. It was found that fresheners with strong scent/flavour and wrapped in plastic nets are used. The coloured wasps are often attracted by these fresheners and tangle themselves to death. Experiments were conducted using commercial refreshers and organically produced lemon grass refreshers. The results indicated that organically produced lemon grass refresher was superior to the commercial refresher used in SRM College of Agricultural Sciences. As these coloured wasps are important as agents natural crop pest agents of chilli, cabbage, etc. It serves as a biological pest control of arthropod population through parasitism. They act as ecosystem engineers forming bio pores while constructing their nests. To maintain biodiversity and reduce the use of insecticides, these coloured wasps form an special position in the ecosystem. Such coloured wasps blue and yellow form a very special to the developing ecosystem of SRM College of Agricultural Sciences. This research suggests that use of natural insect repellents such as Lemmon grass prevents the suicidal deaths of coloured wasps.

Keywords: Biodiversity, Coloured wasps, refreshers, ecosystem, parasitism

ACIDIC VERSUS ALKALINE SPRAY WATER: INFLUENCE OF HIGH ACIDITY AND HIGH ALKALINITY ON THE BIO EFFICACY OF INSECTICIDES.

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Abstract

Chemical insecticides remain one of the most widely used tools against insectpests because of their rapid action, ease of application and economic feasibility. Their performance, however, depends on more than the active ingredient. Water makes up about 95% of a spray mixture, and its pH can drive hydrolysis and loss of active ingredient, particularly under alkaline conditions. Because water pH is easy to measure and adjust, it offers a low-cost way to make chemical control more reliable within integrated pest management. This study compared the effect of highly acidic and highly alkaline spray water on the efficacy of four insecticides against Spodoptera litura. A laboratory experiment was conducted in 2025–26 in a factorial completely randomized design with three replications. Reverse osmosis (RO) water was adjusted to high acidity (pH 4; TDS 97 ppm; EC 0.15 dS m^{-1}) and high alkalinity (pH 9; TDS 98 ppm; EC 0.16 dS m^{-1}), so the two waters differed in pH but not in dissolved salts. The insecticides were emamectin benzoate 5% SG, profenofos 50% EC, spinetoram 11.7% SC, and chlorantraniliprole 9.3% + lambda-cyhalothrin 4.6% ZC, used at recommended concentrations. Spray solutions were allowed to stand for 3 hr before use, simulating the delay between mixing and field application. Efficacy was assessed by a castor leaf-dip bioassay on ten third-instar larvae per replicate. Mortality was recorded at 1, 3, 5 and 7 days after treatment (DAT).

Spray-water pH significantly affected larval mortality at every observation. Acidic water gave consistently higher mortality than alkaline water, and the gap widened over time. At 3, 5 and 7 DAT, mortality was 67.26%, 95.37% and 98.60% in acidic water, against 38.23%, 56.84% and 66.87% in alkaline water. All four insecticides lost efficacy under alkaline conditions. At 7 DAT, mortality in acidic versus alkaline water was 98.60% versus 66.74% for emamectin benzoate, 90.00% versus 56.69% for profenofos, and 99.97% versus 73.48% for spinetoram and 99.97% versus 70% chlorantraniliprole + lambda-cyhalothrin mixture. Profenofos recorded the lowest mortality in alkaline water, consistent with the known sensitivity of

organophosphates to alkaline hydrolysis, although degradation was not measured in this study. Highly alkaline spray water can substantially reduce insecticide performance, whereas acidic water preserves it, even when the solution stands for some hours before application. Checking spray-water pH and bringing alkaline water towards the acidic range are inexpensive steps that can be added to existing pest management programmes. As this was a laboratory bioassay on a single pest, field validation is the next step. The study supports “right water, right chemistry, right application” as a practical basis for more dependable and resilient plant protection.

Keywords: *Spodoptera litura*, pH, acidic water, alkaline water, Bioefficacy.

PHYSIOLOGICAL BASIS OF ENDOPHYTE-MEDIATED RESISTANCE TO FUSARIUM WILT IN BRINJAL

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Abstract

Fusarium wilt is an important soil-borne disease of brinjal (*Solanum melongena L.*) that can cause vascular dysfunction, impaired water transport, reduced plant growth and substantial yield losses. The persistence of Fusarium pathogens in soil makes disease management challenging and necessitates sustainable strategies that combine pathogen suppression with enhancement of host plant resilience. The present study aims to investigate the potential of two selected endophytic bacterial isolates and a plant defence elicitor in enhancing physiological resilience and suppressing Fusarium wilt in brinjal. The experiment will evaluate the individual and interactive effects of these treatments on disease development, plant growth and physiological responses under pathogen challenge. Key parameters will include disease incidence and severity, chlorophyll content, photosynthetic performance, relative water content, membrane stability, proline accumulation, and antioxidant enzyme activities, including superoxide dismutase, catalase and peroxidase. Selected defence-related biochemical markers will also be assessed to elucidate potential mechanisms of induced resistance. Root and shoot biomass, vascular browning and yield-related parameters will be recorded to establish the relationship between physiological resilience and disease suppression.The study is expected to identify effective treatment combinations that reduce disease progression, maintain photosynthetic function and water relations, and strengthen the plant's antioxidant and defence systems. The findings may contribute to the development of an integrated, physiology-based plant protection strategy for sustainable brinjal cultivation.

Keywords: Brinjal, Fusarium wilt, endophytic bacteria, plant physiological resilience, antioxidant defence, induced resistance, integrated disease management

ROLE OF ARTIFICIAL INTELLIGENCE IN AGRICULTURE FOR A SMARTER SUSTAINABLE FUTURE OF INDIAN FARMERS

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Abstract

Indian agriculture is undergoing a significant transformation driven by digital technologies and the growing need for sustainable, climate-resilient food production. Artificial Intelligence (AI) has emerged as a promising tool to address major agricultural challenges, including climate variability, pest and disease outbreaks, water scarcity, declining soil fertility, labour shortages, and fluctuating market prices. The integration of AI with precision agriculture, remote sensing, Internet of Things (IoT), Machine Learning (ML), drones, and predictive analytics offers opportunities to improve farm productivity, resource-use efficiency, and farmers' livelihoods. Indian agriculture stands at a critical crossroads, challenged by climate variability, dwindling water tables, fragmented smallholder landholdings, and escalating input costs. This paper explores the transformative potential of AI, ML, Computer Vision, and IoT in redefining Indian farming from a reactive, labor- intensive model to a proactive, data-driven science. By analyzing empirical studies and institutional frameworks such as the Digital Agriculture Mission and real-world deployments like AI-driven precision advisory tools (e.g., Fasal, Plantix, and multilingual advisory chatbots) the study highlights how AI interventions yield measurable gains: 10–30% improvements in crop productivity, 25–30% reductions in water and fertilizer usage and 30–40% decreases in pest and disease-related losses. This paper explores the potential applications of AI across the agricultural value chain, including crop planning, soil health assessment, weather forecasting, early detection of pests and diseases, precision irrigation, nutrient management, yield prediction, post-harvest management, and market intelligence. AI-enabled decision-support systems can provide timely, location-specific advisories to farmers, helping them make informed decisions while reducing unnecessary expenditure on agricultural inputs. In the Indian context, the convergence of AI with digital agriculture initiatives, mobile-based advisory services, and agricultural extension institutions can strengthen technology dissemination and improve access to scientific knowledge, particularly among small and marginal farmers. Furthermore, AI can support climate-smart

agriculture by anticipating weather-related risks, optimizing water and fertilizer use, and facilitating the

adoption of resilient cropping practices. However, challenges such as limited digital literacy, inadequate rural connectivity, high initial investment, fragmented agricultural data, language barriers, and concerns regarding data privacy and affordability must be addressed to ensure inclusive adoption. Strengthening public–private partnerships, developing farmer-centric AI tools in regional languages, promoting capacity-building programmes, and integrating AI with the extension services of Krishi Vigyan Kendras (KVKs) are essential for effective implementation. In conclusion, responsible and inclusive application of AI can contribute to a smarter, more productive, economically viable, and environmentally sustainable agricultural system in India, empowering farmers to make data-driven decisions and enhancing their resilience to emerging agricultural challenges.

Keywords: Artificial Intelligence, Digital Agriculture, Precision Farming, Climate-Smart Agriculture, Sustainable Agriculture, Indian Farmers, Agricultural Extension.

ANTIFUNGAL POTENTIAL OF *Schizophyllum commune* FOR SUSTAINABLE MANAGEMENT OF PLANT-PATHOGENIC FUNGI

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Abstract

Fungal diseases are major constraints to agricultural productivity, causing substantial losses in crop yield and quality. The limitations associated with conventional fungicides have increased interest in biologically derived alternatives for sustainable plant disease management. Schizophyllum commune, a lignicolous basidiomycetous mushroom commonly associated with decaying wood, represents a potential source of bioactive compounds with antifungal properties. Previous investigations have reported inhibitory effects of its crude extracts and culture-derived metabolites against various fungal pathogens, including Fusarium oxysporum, Colletotrichum gloeosporioides and Botrytis cinerea. Despite reports of antifungal activity associated with Schizophyllum commune, its potential for managing plant-pathogenic fungi remains inadequately explored, particularly with respect to the comparative efficacy of different extracts, the identification of responsible bioactive compounds, and their mechanisms of antifungal action. Furthermore, the relationship between in vitro inhibitory activity and disease suppression under greenhouse and field conditions requires systematic evaluation. Thus, exploring S. commune may contribute to the development of environmentally sustainable strategies for managing plant-pathogenic fungi and reducing dependence on conventional fungicides.

Keywords: *Schizophyllum commune*, antifungal activity, phytopathogens, bioactive compounds and crude extract.

ACOUSTIC DETECTION OF PULSE BEETLE, *Callosobruchus chinensis* (L.) IN STORED FOOD LEGUMES

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Abstract

The Pulse beetle, *C. chinensis* (L.), is a major pest responsible for significant damage to stored food legumes, leading to considerable post-harvest losses worldwide. Traditional pest monitoring techniques such as manual inspection and traps, often lack precision and are labor-intensive, making them inefficient for large-scale storage systems. This study focuses on leveraging an acoustic detection system as a novel approach for automated pest monitoring, integrating it into effective integrated pest management (IPM) strategies. Acoustic profiling of C. chinensis in green gram and cowpea under varying infestation levels (0-500 insects) was performed using STM microelectronics and HTC SL digital sound meters. Sound intensity values (in decibels) increased consistently with insect density, demonstrating a strong positive correlation. PCA analysis of acoustic data showed distinct clustering patterns *Corresponding to insect densities, indicating the feasibility of using bioacoustics for non-invasive pest detection. By using STM microelectronics, Sound amplification for C. chinensis ranges from 32.10 dB (uninfested sample) to 62.80 dB (500 insects) at 50 amplifications in green gram whereas in cowpea, it varied from 36.16 dB (uninfested samples) to 56.15 dB (500 insects). And also by using HTC SL Mini digital meter, insect sound intensity was measured for C. chinensis in green gram and cowpea across densities ranging from 0 to 500 insects. In green gram, C. chinensis exhibited a steady rise in acoustic intensity from 22.51 dB (control) to a peak of 47.34 dB at 500 insects, while in cowpea, the sound intensity increased from 22.34 to 44.62 dB, demonstrating a strong positive correlation with insect density and validating the sensitivity and effectiveness of acoustic detection for early and scalable bruchid infestation monitoring.

Keywords: Acoustic, green gram, MEMS microphone, and Pulse beetle, *C. chinensis*

INTEGRATING PHEROMONE-BASED SURVEILLANCE AND MATING DISRUPTION FOR SUSTAINABLE MANAGEMENT OF RICE YELLOW STEM BORER (*Scirpophaga incertulas* WALKER)

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Abstract

Rice yellow stem borer *(Scirpophaga incertulas)* Walker is a major pest of rice, causing dead-heart symptoms during vegetative growth and white-ear symptoms during reproductive development. Dependence on conventional insecticides raises concerns regarding environmental contamination, adverse effects on beneficial organisms, and increasing production costs. Pheromone-based technologies offer an innovative approach to sustainable pest management by exploiting insect chemical communication for population monitoring and behavioural control. This review examines recent advances in sex pheromone-based surveillance and mating disruption, focusing on their integration into rice integrated pest management (IPM). Pheromone traps facilitate the monitoring of adult male activity and seasonal population fluctuations, helping identify periods of increased pest risk. Recent research has explored combining pheromone-trap observations with remote-sensing indices to improve spatial and temporal pest surveillance. Mating disruption involves deploying synthetic sex pheromones to interfere with mate-finding behaviour, thereby reducing successful mating and subsequent pest infestation. Slow-release formulations, including wax- based dispensers, offer opportunities for sustained pheromone emission and prolonged field effectiveness. Multi-location field evaluations in Indonesia have demonstrated reductions in trap catches and crop damage under pheromone-mediated mating disruption, while recent studies in Karnataka have reported reduced stem-borer damage and improved grain yield. Despite these promising outcomes, effectiveness depends on dispenser placement, pheromone release characteristics, treatment-area size, surrounding pest populations, and timing of application. Integrating pheromone surveillance with area-wide mating disruption, crop-stage-specific damage assessment, conservation of natural enemies, and need-based insecticide application couldimprove management precision and reduce unnecessary chemical interventions. Further research should prioritise locally validated action thresholds, cost-effective dispenser technologies, and multi-season field evaluations. Integrating these approaches into farmer-

oriented decision-support systems offers considerable potential for environmentally sustainable and economically viable rice production.

Keywords: *Scirpophaga incertulas*; sex pheromone; mating disruption; pest surveillance; integrated pest management; sustainable rice production.

RELIABILITY FRAMEWORK FOR EVALUATING MICROBIAL CROP PROTECTION UNDER COMBINED HEAT, DROUGHT AND PATHOGEN PRESSURE

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Abstract

The crops are being exposed to temperature, drought and pathogen stresses together but not alone. The utilisation of microbial crop protectants like antagonistic microorganisms, PGPR, endophytes and consortia has been suggested as an eco-friendly method. Disease control ability, growth promotion and in vitro antagonism have been considered as the criteria for screening of these microorganisms. In this review, an attempt has been made to determine whether these microbes can suppress diseases under conditions of temperature, drought and pathogen stresses together. Furthermore, this review includes the microbial mechanism, plant pathogen interaction, stress conditions (biotic/abiotic) and the Trait-Based Reliability Framework (TBRF). This framework distinguishes five independent performance factors: stress resistance and survival, establishment and persistence in the target niche, direct antagonism to the pathogen, host effects, and disease control and agronomical results. There are four extensions to this framework: triple window matching between the microorganism, the pathogen and the stressed plant; failure classification into five classes; claim ceiling to specify the minimal proof required. Eight microbial studies and one stress-pathogen study were examined in an initial evidence map. The aim of this review is to promote reproducible research and claims proportional to the evidence.

Keywords: Microbial biocontrol; combined stress; disease suppression; field validation; reliability framework

MANAGING INSECT PESTS SUSTAINABLY BY USING AGRICULTURAL AND INVASIVE WEEDS AS BIOPESTICIDES

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Abstract

The increasing dependence on synthetic insecticides in modern agriculture has raised concerns regarding environmental pollution, pesticide residues, the development of insecticide resistance, and adverse effects on beneficial organisms. These challenges have encouraged the exploration of plant-derived biopesticides as alternative tools for sustainable insect pest management. Agricultural and invasive weeds, commonly regarded as unwanted plants, contain diverse bioactive compounds that may possess insecticidal, repellent, antifeedant and insect growth-regulating properties. Their potential utilization offers an innovative approach to transforming problematic weeds into valuable resources for crop protection.Several weed species have been investigated for their pesticidal properties, including Lantana camara, Ageratum conyzoides, Parthenium hysterophorus, Calotropis gigantea, Datura metel, Datura stramonium, Ricinus communis, Ipomoea carnea, Tridax procumbens, Argemone mexicana, Achyranthes aspera, Leucas aspera and Polygonum hydropiper. These plants contain secondary metabolites such as alkaloids, terpenoids, flavonoids, phenolics, tannins and saponins, which may interfere with insect feeding, survival, development and reproduction. Krishna et al. (2013) demonstrated the potential of extracts prepared from agricultural weeds against pest infestations in different crops. Similarly, Balabanova et al. (2024) reviewed the insecticidal potential of Lantana camara, highlighting its bioactive constituents and prospects for insect management. Lengai et al. (2020) and Merchant (2022) further discussed the importance of botanical pesticides, their phytochemical properties, mechanisms of action and role in sustainable crop protection. Depending on the plant species, extraction method and target insect, weed-derived preparations may contribute to pest suppression through multiple biological mechanisms. Their integration into integrated pest management (IPM) programmes can potentially reduce dependence on synthetic insecticides, support biodiversity conservation, minimize persistent pesticide residues and improve the utilization of locally available

biological resources. In addition, utilizing unwanted weeds as raw materials may provide a cost-effective option for resource-limited farmers while contributing to weed management and circular agricultural practices. Despite these promising prospects, important challenges remain, including variability in active compound concentrations, inconsistent field performance, formulation stability, phytotoxicity and potential toxicity to beneficial insects and other non-targetorganisms. Therefore, systematic laboratory and field evaluations, chemical characterization,dose standardization and environmental safety assessments are necessary before recommending widespread agricultural use. In conclusion, weed-derived biopesticides represent a promising research area in entomology, offering opportunities to combine sustainable insect pest management with the productive utilization of invasive and agricultural weeds. Further research and integration with established IPM strategies may strengthen their contribution to environmentally responsible and economically viable agriculture.

Keywords: Botanical insecticides, Integrated pest management, Insect pests, Sustainable agriculture, Weed-derived biopesticides.

AI-DRIVEN CROP DISEASE DETECTION FOR SUSTAINABLE AGRICULTURE

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Abstract

Plant diseases remain one of the most serious threats to global crop production and food security, and conventional detection based on visual inspection is slow, subjective, and impractical at scale. Across the literature, automated detection follows a common pipeline of image acquisition, preprocessing, segmentation, feature extraction, and classification, using machine learning classifiers such as support vector machines, random forests, and artificial neural networks and, increasingly, deep learning, particularly convolutional neural networks (CNNs) with transfer learning. Reported accuracies are high: a segmentation-first system combining HSV colour-space preprocessing with an EfficientNet-B4 classifier reached 99.18% on leaf images and 83.33% under field conditions, while reviews of tomato, chilli, potato, and cucumber studies document many CNN models exceeding 95% accuracy. Beyond identification, AI enables severity estimation, early warning, precision application of fungicides and pesticides, continuous surveillance through drones and satellites, and decision support systems that can reduce chemical use and environmental impact. Lightweight models and mobile applications further extend these tools to resource-limited farmers. Nevertheless, the reviewed studies converge on shared limitations. Most models are trained on laboratory-style, single-leaf images from public datasets such as Plant Village, so performance declines in complex field environments with cluttered backgrounds, variable lighting, and multiple co-occurring diseases or look-alike symptoms. Small, imbalanced, or non-diverse datasets restrict generalization, and the black-box nature of deep learning limits interpretability and farmer trust. Field-scale and remote-sensing-based detection remains less mature, often identifying disease only after it has spread widely, which leaves a gap between detection and treatment decisions. Limited infrastructure, connectivity, and technical capacity in smallholder settings further hinder adoption. Future directions include larger and field-realistic open datasets, explainable AI, edge and mobile deployment, integration with IoT sensors, drones, and multispectral data, and federated and multimodal learning, together with farmer training and

collaboration among researchers, policymakers, and technology developers. Overall, AI offers a promising route to timely, targeted, and sustainable disease management, but real-world validation and accessible deployment are essential to realize this potential.

Keywords: Artificial intelligence, Crop disease detection, Deep learning, Precision agriculture, Sustainable crop protection

BIOCHAR AS A MULTIFUNCTIONAL PLATFORM FOR MICROBIAL AND BOTANICAL CROP PROTECTION

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Abstract

The increasing dependence on synthetic pesticides for the management of plant pathogens and insect pests has raised concerns regarding pesticide residues, resistance development, environmental contamination and disruption of beneficial soil microorganisms. Biochar offers a promising multifunctional approach for sustainable crop protection because of its porous structure, high surface area, nutrient-retention capacity and ability to modify the soil–plant–microbe interface. The present concept proposes a biochar-enabled integrated bioprotection system combining biochar with beneficial microorganisms and botanical pest- management agents for simultaneous suppression of soil-borne pathogens and insect pests. Biochar can serve as a protective habitat and carrier for beneficial microorganisms such as Trichoderma and Bacillus, while its adsorption properties may facilitate the gradual release and persistence of bioactive botanical compounds. The proposed system is expected to improve rhizosphere microbial activity, restrict pathogen establishment, enhance root growth and stimulate plant defense responses. In addition, biochar-mediated improvement in plant nutritional and physiological status increase crop resilience against pest attack. The integrated treatment involving biochar, microbial biocontrol agents and neem-based (biochar) botanical inputs is hypothesized to provide greater crop protection than their individual application. Evaluation of disease incidence, pest population, plant growth, yield, rhizosphere microbial activity and selected plant-defense responses would provide a comprehensive assessment of the technology. This biochar–microbe–botanical consortium represents a promising circular and low-residue strategy for integrating soil health management with crop protection. The approach could contribute to resilient agricultural systems by reducing dependence on synthetic pesticides while simultaneously improving soil biological health and crop productivity.

Keywords: Synthetic Pesticides, Biochar, Botanical Pest Management, Soil Health Management.

EVALUATING ADJUVANT EFFECTS ON UAV-BASED HERBICIDE SPRAY PERFORMANCE: IMPLICATIONS FOR DROPLET DEPOSITION CHARACTERISTICS, SPRAY DRIFT CONTROL AND WEED MANAGEMENT IN TRANSPLANTED RICE

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Abstract

Weed infestation is a major constraint in transplanted rice, reducing crop growth, nutrient availability, and grain yield. Although UAV-based herbicide application can reduce spray volume, labour requirements, and operator exposure, its effectiveness under low- volume spraying depends strongly on droplet formation, deposition, coverage, and retention on weed foliage. Adjuvants can modify these spray characteristics and improve herbicide performance. Therefore, a field experiment was conducted during the winter (Navarai) seasons (January–May) of 2025 and 2026 at Chengalpattu, Tamil Nadu, semi-arid tropics of india to evaluate the effect of different adjuvants on UAV-applied herbicide for weed management in transplanted rice. The experiment used seven treatments comprising florpyrauxifen-benzyl + cyhalofop-butyl @ 150 g ha^{-1} applied through UAV with silicon- based, APSA, and methylated seed oil (MSO) adjuvants, UAV spraying without adjuvant, conventional knapsack spraying, weed-free check, and weedy check. The herbicide was applied at 20 days after transplanting, with UAV spraying performed at 40 L ha -1 . Among the UAV treatments, the silicon-based adjuvant produced the most favourable spray characteristics, recording higher volume median diameter (767,792 µm), deposition (1.57,1.60 µL cm -2), area coverage (39.60, 40.64%), and droplet density (1.84, 1.85 deposits cm -2), together with a narrower relative span than the other UAV treatments. Improved spraydeposition resulted in greater weed suppression. The silicon-based treatment recorded lower total weed density and dry weight, higher weed control efficiency (89.95% at 40 DAT and 81.48% at 60 DAT), and the highest herbicide efficiency index (11.99). Grain yield reached 5395 kg ha -1 , statistically comparable with knapsack spraying (5326 kg ha -1), while the weedy check produced only 1284 kg ha -1 . Overall, the study demonstrates that suitable adjuvant incorporation, particularly a silicon-based adjuvant, can substantially

improve the efficiency of low-volume UAV herbicide application and provide weed control and crop productivity comparable with conventional knapsack spraying.

Keywords: Weed dynamics, Adjuvants, Drone, Transplanted rice, Florpyrauxifen-benzyl + Cyhalofop-butyl.

INNOVATION IN AGRICULTURAL AND BIOLOGICAL SCIENCES FOR SUSTAINABLE CROP PROTECTION

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Abstract

Crop protection is essential for ensuring global food security, improving agricultural productivity, and maintaining the sustainability of farming systems. However, excessive dependence on synthetic pesticides has contributed to environmental pollution, pesticide resistance in insect pests and pathogens, and the loss of beneficial organisms. Therefore, innovative approaches integrating agricultural and biological sciences are increasingly important for developing sustainable crop protection strategies. Recent advances in biological control, microbial biopesticides, plant-based products, host plant resistance, molecular breeding, and precision agriculture offer promising alternatives to conventional chemical-intensive practices. Biological control employs beneficial microorganisms, including Bacillus, Trichoderma, and Beauveria, to suppress plant pathogens and insect pests. Advances in molecular biology and genomics have improved the identification of resistance genes and enabled the development of crop varieties with enhanced resistance to pests and diseases. Furthermore, integrated pest management (IPM), combining biological control agents, resistant cultivars, cultural practices, pest monitoring, and judicious pesticide application, can reduce chemical inputs while maintaining crop productivity. Emerging technologies such as artificial intelligence, remote sensing, and digital pest surveillance also support the early detection of pest outbreaks and the precise application of crop protection measures. The integration of these innovations can improve resource-use efficiency, protect beneficial organisms, reduce environmental risks, and strengthen agricultural resilience under changing climatic conditions. Nevertheless, challenges related to the field-level effectiveness of biological products, production costs, farmer awareness, and accessibility require further attention. Strengthening research, extension services, and collaboration between agricultural and biological scientists is therefore essential. Overall, integrating biological solutions, genetic resistance, and precision technologies offers a promising pathway toward environmentally responsible, economically viable, and sustainable crop protection.

Keywords: Sustainable crop protection, Biological control, Biopesticides, Integrated pest management, Host plant resistance, Precision agriculture.

ESSENTIAL OILS AS NEXT-GENERATION BIOPESTICIDES: INNOVATIVE STRATEGIES FOR SUSTAINABLE INSECT PEST MANAGEMENT

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Abstract

Synthetic insecticides raise concerns about resistance, pollution, biodiversity loss, and harm to human health and non-target organisms. These concerns have increased interest in plant-derived essential oils (EOs) as potential biopesticides. EOs are volatile mixtures of compounds such as eugenol, thymol, carvacrol, limonene, linalool, and 1,8-cineole, many of which have shown activity against agricultural and stored-product pests. Essential oils can act through contact toxicity, fumigation, repellency, feeding deterrence, oviposition inhibition, and disruption of insect development and reproduction. Some constituents may affect physiological pathways, including octopaminergic signalling and acetylcholinesterase activity. Their diverse chemistry offers several possible modes of action, although more research is needed to establish whether this diversity can meaningfully delay resistance. Practical use is constrained by volatility, sensitivity to light and heat, poor water solubility, variation in chemical composition, and inconsistent field performance. Nanoemulsions, microencapsulation, polymer-based carriers, and controlled-release formulations may protect active compounds and prolong their effects. Combining EOs with other compatible pest-management tools could also improve control and reduce reliance on synthetic insecticides. Analytical approaches such as GC–MS, metabolomic profiling, and chemometric analysis can help identify active compounds and standardise formulations. Within integrated pest management, EO-based products may help manage resistance and reduce pesticide residues when selected and applied appropriately. However, natural origin does not guarantee safety or sustainability. Their effects on crops, pollinators, natural enemies, mammals, and the environment—as well as their costs and regulatory requirements—must be assessed. Further research should prioritize reproducible formulations, standardized efficacy tests, trials across different field conditions, and life-cycle assessments. Overall, essential oils are a promising basis for next-generation biopesticides, but dependable use in agriculture will require rigorous safety testing, scalable production, and evidence that laboratory effectiveness translates into consistent field performance.

Keywords: Essential oils; botanical biopesticides; nanoformulation; controlled-release delivery; insecticide resistance; integrated pest management.

PGPR-MEDIATED TRANSGENERATIONAL IMMUNE PRIMING IN PLANTS

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Abstract

Plants possess sophisticated defense mechanisms to protect themselves against pathogens. Plant immune priming is a phenomenon in which prior exposure to a stimulus prepares a plant to activate faster or stronger defense responses upon subsequent pathogen attack. Priming can be induced by chemical elicitors and beneficial microorganisms, offering potential applications in sustainable crop protection. An emerging area of research is transgenerational immune priming (TGIP), in which exposure to a priming stimulus in one generation is associated with enhanced defense responses in subsequent generations. Epigenetic mechanisms, including DNA methylation, may contribute to the persistence of stress-related information across generations. Understanding these mechanisms could provide new approaches to improving crop resilience and reducing dependence on conventional disease-management strategies.This presentation will introduce the fundamental principles of plant immunity and immune priming, discuss methods of inducing priming, and explore the potential mechanisms underlying transgenerational defence responses. It will focus on a 2026 study, titled Plant growth-promoting rhizobacteria-induced transgenerational immune priming strengthens wheat defense against Bipolaris sorokiniana. The researchers investigated the effects of priming wheat seeds with the beneficial bacterium Bacillus amyloliquefaciens B16. They reported enhanced resistance to Bipolaris sorokiniana the pathogen responsible for spot blotch disease, in the second-generation progeny of primed plants. DNA methylation patterns observed in the parental generation suggested a possible role for epigenetic regulation. Overall, TGIP represents a promising research direction for understanding plant stress memory and developing sustainable crop-protection strategies.

Keywords: Plant immune priming; transgenerational immune priming; epigenetics; wheat; beneficial bacteria; plant disease resistance.

SILENT POLLINATORS UNDER THREAT: PESTICIDE TOXICITY, SUBLETHAL EFFECTS AND CONSERVATION OF NON-APIS BEES

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Abstract

Non-Apis bees, including solitary bees, bumble bees, mason bees, leafcutter bees and stingless bees, are important pollinators of wild plants and agricultural crops. Despite their ecological and economic significance, these pollinators receive comparatively less attention than the honey bee (Apis mellifera) in pesticide risk assessment and conservation programmes. The widespread application of agricultural pesticides exposes non-Apis bees to chemical residues through contaminated pollen, nectar, soil, nesting materials and direct contact during foraging. Although pesticide exposure may cause acute mortality, sublethal effects can also compromise pollinator fitness without producing immediate visible signs of toxicity. These effects include impaired learning and memory, altered foraging behaviour, reduced locomotor activity, disrupted development, decreased reproductive success and changes in colony growth and survival. Neonicotinoids have received considerable research attention, while the effects of pesticide mixtures, fungicides, herbicides, and other insecticide classes remain inadequately characterized across diverse bee taxa. Furthermore, substantial differences in nesting habits, foraging ranges, life cycles and social organization may influence pesticide exposure and species-specific susceptibility. This review aims to synthesize current knowledge of pesticide toxicity and sublethal effects in non-Apis bees, emphasizing the ecological consequences of chronic and field-realistic exposure. It also examines limitations in existing pesticide risk assessment frameworks, particularly the reliance on honey bees as surrogate species and the insufficient consideration of behavioural, reproductive and population-level endpoints. Potential conservation approaches include integrated pest management (IPM), reducing pesticide application during flowering and peak pollinator activity, maintaining pesticide-free nesting habitats, restoring diverse floral resources, conserving natural and semi-natural vegetation and providing suitable nesting substrates for solitary bees. The review further highlights the need for species- specific toxicity testing, long-term field studies and assessments of interactions between pesticides and other environmental stressors. Integrating eco-toxicological research with habitat management and evidence-based pesticide regulation

is essential for protecting non-Apis bees and sustaining pollination services. A more inclusive conservation framework that recognizes the diversity of bee species and their ecological requirements will contribute to resilient agricultural ecosystems and long- term pollinator conservation.

Keywords: Non-Apis Bees, Pesticide Toxicity, Sublethal Effects, Pollinator Conservation, Eco-Toxicology, Integrated Pest Management.

MOLECULAR CHARACTERIZATION OF PSMB5 GENE OF *Corcyra cephalonica* FOR RNAi MEDIATED SUSTAINABLE PEST MANAGEMENT

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Abstract

The proteasome subunit beta 5 (psmb5) gene plays an important role in protein degradation and cellular function. Molecular characterization of psmb5 gene in Corcyra cephalonica (Rice moth), a major stored grain pest, may help in exploring its potential as a target for RNA interference (RNAi)-based pest management. The present study was carried out to identify the psmb5 gene from *C. cephalonica* as an effective target of pest management. For this, C. cephalonica genome was retrieved and psmb5 gene was analysed using in silico: experimental methods. The psmb5 gene sequence of *Drosophila melanogaster* was selected as a reference to identify its orthologs in *C. cephalonica*. BLASTn and tBLASTn searches identified a single gene candidate of psmb5 gene. The characterized gene consists of an 843 bp coding sequence encoding a 280 amino acid protein, with a predicted pI of 5.99 and six exons. The presence of a conserved NTN hydrolase domain identified through the Conserved Domain Search (CD-search) further confirmed its identity as a proteasome beta subunit. Multiple sequence alignment (MSA) was then performed to identify the sequence conservation of psmb5 gene in *C. cephalonica*. Phylogenetic analysis revealed distinct evolutionary pattern of psmb5 gene among the lepidopteran insects. The dsRNA designed from the less conserved region of the gene and the subsequent in vitro bioassay using nano delivery methods revealed psmb5 as a promising target for RNAi-based management of C. cephalonica. In conclusion, the study identified psmb5 as an effective target for developing RNA-based biopesticide for the management of *C. cephalonica.*

Keywords: proteasome subunit beta 5, PSMB5, *Corcyra cephalonica*, rice moth, RNAi

BIOFORTIFICATION OF MILKY MUSHROOM (*Calocybe indica*) WITH IRON AND ZINC: EFFECTS ON MYCELIAL GROWTH, BIOLOGICAL EFFICIENCY AND NUTRIENT DYNAMICS IN SPENT SUBSTRATE

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Abstract

Micronutrient malnutrition or "hidden hunger", driven largely by iron and zinc deficiencies, remains a major concern in cereal-based diets of developing regions. Biofortification offers a sustainable, food-based solution and edible mushrooms are well suited to it because their mycelium readily absorbs minerals from the substrate. Milky mushroom (Calocybe indica), a tropical species with high consumer acceptance, is a practical candidate, but mineral doses must be optimized since excess levels can suppress growth and yield. This study evaluated iron ($FeSO_4$) and zinc ($ZnSO_4$) fortification at 10, 25 and 50 mM on mycelial growth, growth and yield attributes and physicochemical properties of the spent substrate of sC. indica. Radial mycelial growth was assessed in vitro on fortified plates, followed by bed cultivation on a sawdust substrate supplemented with rice bran (20 per cent), gypsum (1 per cent) and sucrose (1 per cent), which supported healthy mycelial growth in all fortification treatments. Spent substrate was analysed for pH, electrical conductivity, organic carbon and C:N ratio. $FeSO_4$ enhanced radial mycelial growth up to 25 mM (89.20 mm against 79.60 mm in the control), with a slight decline at 50 mM (86.40 mm), whereas $ZnSO_4$ suppressed growth progressively, falling to 68.20 mm at 50 mM. In beds, $FeSO_4$ at 25 mM recorded the shortest spawn run (29 days) and the highest pileus diameter (9.48 cm), stipe length (10.96 cm), average fruiting body weight (69.60 g), yield (752 g perbed) and biological efficiency (75.2 per cent), about 24 per cent above the control. $ZnSO_4$ at 10 mM was comparable to the control (625 g against 606 g per bed), while 50 mM produced the lowest yield (548 g per bed) and biological efficiency (54.8 per cent), nearly 10 per cent below the control. Compared with fresh sawdust (pH 7.12, EC 0.84 dS m^{-1}, organic carbon 56.0 per cent, C:N 235:1), the spent substrate showed lower pH (6.19–6.56), higher EC, reduced organic carbon and a markedly narrower C:N ratio (24.9 - 31.7:1), with the greatest changes at the 50 mM doses, indicating potential for reuse as compost or soil amendment. The study identifies 25 mM $FeSO_4$ as the optimum fortification level for growth and productivity of C. indica, while zinc should be restricted to low doses (not exceeding 10 mM) to avoid yield depression. It provides a low-cost sawdust-based substrate

and fortification protocol for milky mushroom, along with evidence supporting spent substrate valorisation as compost.

Keywords: Biofortification; Calocybe indica; Micronutrients; Substrate fortification; Spent mushroom substrate

MANAGEMENT OF SEED–BORNE *Aspergillus niger* IN THROUGH SEED TREATMENT AND ITS EFFECT ON SEED STORABILITY IN TOMATO CV *Lycopersicum esculentum* L. PKM -1

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Abstract

Tomato is a one of the most popular vegetable crops grown in around the world, India and Tamil Nadu. Currently there is a lack of different seed treatments for bacterial pathogens, with based on compounds (the only chemical treatments permitted under organic farming standards) only providing partial control. Treatments assessed were acidified nitrite (a treatment previously shown to control the seed-borne fungal disease *Didymella lycopersici*), antagonistic strains of *Bacillus spp*. and compost extracts, which were not previously evaluated as treatments for seed-borne diseases. Seed was extracted from the collected fruits and subjected to various seed health testing methods. Seven samples showing higher incidence of seed borne fungi were selected for studying the location and transmission of the pathogen. The results revealed that, *Alternaria solani* percentage of infection was detected to be higher under Standard Blotter Method for control (27%). Locality of *Alternaria solani* ranged up to 24% inT 14 *Trichoderma viridae* (10%), 23% in T4 Gibberellic Acid (10%) and 19 % in T 13 *Trichoderma viridae* (5%) and the T 5 Nano Urea (5%) 16% in T 9 Humic Secret (5%) 15% in and the lowest infection Standard Blotter Method of T 3 Gibberellic Acid (5%) 7% best treatment laboratory experiments shown 42% seed to seed transmission of the pathogen.

Keywords: Tomato, *Alternaria solani*, seed borne, transmission

SURVEY AND IDM PACKAGE FOR COCONUT ROOT (WILT) DISEASE IN TAMIL NADU, INDIA

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Abstract

Phytoplasma associated with root (wilt) disease in coconut is a serious threat and causes heavy economic loss to the coconut farmers in Kerala and Tamil Nadu in India. A roving survey was carried out during 2021 -2026 to assess the disease incidence in Coimbatore, Tirupur, Dindigul, Theni, Tenkasi, Tirunelveli and Kanyakumari districts. From the results, Cumbum block in Theni district, Tenkasi block in Tirunelveli (Tenkasi) district and Kuruthancode block in Kanyakumari district were identified as hot spot area for root (wilt) incidence. The disease is generally recognized based on leaf symptoms, but the development of foliar symptoms in coconut palms is very slow and there is a time lag between infection and symptom expression. The maximum disease incidence was observed in Tirunelveli (16.77%) followed by Theni (7.83%) districts. Coimbatore district which houses the largest coconut plantations in Tamil Nadu exhibited up to 12.97% of disease incidence in Pollachi north and south blocks between 2024 and 2025. Though several approaches have been developed to manage the disease, there is no effective strategy to prevent it in the coconut palms. A field trial conducted at Aliyarnagar village of Anaimalai block in Coimbatore district revealed that the application of fertilizers at recommended dose, Root feeding of TNAU coconut tonic @ 40 ml per tree mixed with 160 ml of water at six month intervals (yearly two times), Soil application of 100 g Trichoderma asperellum and 100 g Bacillus subtilis by mixing with 5 kg farm yard manure per tree at three month intervals (yearly 4 times).along with root treatments with hexaconazole 5EC at 2ml/ 100 ml of water per palm at monthly intervals effectively reduces the symptoms of root (wilt) disease and along with Mass multiplied TNAU “Cococon” should be applied around root zone @ 2 liters per tree mixed with 8 liters of water at 3 month intervals However, discontinuation of root treatment and other management practices would result in reemergence of new fronds and nuts was effective in reducing the disease incidence from 25.14 to 5.13% after two years of treatment

Keywords: Coconut, Cocos nucifera L., root wilt, survey, disease severity, disease management, IDM packages.

ECO-FRIENDLY STRATEGIES FOR THE MANAGEMENT OF BACTERIAL LEAF BLIGHT IN POMEGRANATE

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Abstract

Bacterial leaf blight (BLB) of pomegranate, caused by Xanthomonas axonopodis pv. punicae (XAP), is a devastating disease that significantly limits the productivity and profitability of pomegranate cultivation in India. Yield losses due to BLB have been ranging from 30 to 80% under severe disease incidence, particularly when infection occurs during the early flowering and fruit development stages. The present investigation was undertaken to develop an eco-friendly and sustainable management strategy for BLB through the exploration of native biocontrol agents and their consortia application. A roving survey was conducted across key pomegranate-growing regions of Tamil Nadu to assess the incidence and severity of BLB. The survey revealed widespread occurrence of the disease with varying intensities across districts. The highest leaf incidence (36.15%) and severity (21.17%) were recorded at Palarpatti in Theni district, while the lowest (13.98% incidence, 5.00% severity) was recorded at Coonoor in Nilgiris. The variation in disease expression was associated with environmental conditions. The pathogen was isolated using the tissue segment method and typical yellow, mucoid colonies were characterized as XAP through biochemical tests and confirmed through molecular identification using 16S rRNA. A total of 38 microbial isolates including bacteria, fungi and actinomycetes were screened for antagonistic activity. Amongthese, three bacterial isolates UBL6 (Bacillus subtilis), UBL7 (*B. amyloliquefaciens*) andUBL9 (B. velezensis) which isolated from pomegranate leaves (Endophytes) exhibited strong in vitro antagonism against XAP. These isolates were mutually compatible and exhibited beneficial biochemical traits such as cellulase activity and siderophore production. Further GC-MS analysis of the promising biocontrol isolates confirmed the production of various bioactive metabolites with antimicrobial and plant growth-promoting properties. A liquid bio- formulation based microbial consortium was developed using UBL6, UBL7 and UBL9 isolates and its shelf life was enhanced with amendments, which retains bacterial cell viable still after 60 days period

under CFU enumeration. Glasshouse and field experiments demonstrated that foliar application of the microbial consortia at 1% effectively reduced disease incidence (61.01% in glasshouse; 49.8% in field) and promoted flowering and also increased the fruit yield (13.9 kg/tree) when compared to the untreated control (9.8 kg/tree). The results were statistically on par with the chemical treatment (Kasugamycin + COC), indicating potential of developed microbial consortia as a sustainable and eco-friendly alternative for pomegranate BLB management.

Keywords: Pomegranate, ecofriendly *Bacillus amyloliquefaciens*, Bacterial Leaf Bligh, Disease management.

REVOLUTIONIZING POST-HARVEST MANAGEMENT THROUGH CRISPR-BASED GENOME EDITING AND BIOTECHNOLOGY

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Abstract

A significant problem in global agriculture is post-harvest losses brought on by microbial infections, physiological deterioration, and abiotic stress; these losses lower food availability and farmer revenue while raising financial burdens. Conventional methods, such as chemical treatments and traditional breeding, have only offered a few, frequently unsustainable answers. New developments in biotechnology and CRISPR-based genome editing present revolutionary chances to improve post-harvest management techniques. Crop genomes can be precisely and specifically modified using CRISPR-Cas systems, which enables the quick production of cultivars with better resistance to bacterial and fungal diseases, delayed ripening, and increased storage condition tolerance. Targeting susceptibility genes can improve resistance to post-harvest illnesses such fruit rots, whereas altering genes controlling ethylene production and cell wall disintegration can greatly increase shelf life. Simultaneously, genome editing is complemented by biotechnological technologies such as RNA interference (RNAi), synthetic biology, and bio stimulant integration to produce multi-layered protection and quality enhancement systems. These developments improve food safety and sustainability by lowering the need for chemical fungicides. Additionally, functional genomics research is made easier by CRISPR-based methodologies, which provide a greater understanding of host-pathogen interactions during transportation and storage. Even if public acceptance, off-target consequences, and regulatory frameworks continue to be major obstacles, further study and development of gene-editing technologies have enormous potential. A paradigm change in post-harvest disease management and quality preservation can be accomplished by fusing CRISPR with cutting-edge biotechnology platforms. This will guarantee food security, cut waste, and promote a sustainable agricultural future.

Keywords: Post-harvest management, CRISPR-Cas, genome editing

DECIPHERING GENETIC VARIABILITY AND HOST RESISTANCE TO STRENGTHEN MYMV MANAGEMENT IN MUNG BEAN

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Abstract

Mung bean (*Vigna radiata L.)* is an important pulse crop cultivated across Asian and African countries contributing to nutritional security through its approximately 24% digestible protein content. However, its productivity in India remains below the global average due to biotic and abiotic stresses posing significant challenges to crop production. Among these, mung bean yellow mosaic disease caused by Mung bean Yellow Mosaic Virus (MYMV) is a major constraint, resulting in yield losses of up to 100% 1 . Identifying genetic variability for yield-related traits and sources of disease resistance is therefore essential for developing improved cultivars and strengthening sustainable crop protection. In this context, the present study evaluated 302 mung bean genotypes including Advanced Breeding Lines (ABLs) and germplasm accessions for genetic variability and MYMV resistance under natural field conditions. Analysis of variance for eight yield and yield-contributing traits revealed significant differences among genotypes for all traits except days to 50% flowering, indicating substantial genetic variability. The narrow differences between Phenotypic Coefficient of Variation (PCV) and Genotypic Coefficient of Variation (GCV) suggested limited environmental influence on these traits 2 . Seeds per pod exhibited the highest PCV and GCV while seed yield per plant recorded values of 62.41% and 62.21%, respectively. The lowest PCV and GCV were observed for days to 50% flowering and days to maturity. High broad-sense heritability coupled with high Genetic Advance as a percentage of Mean (GAM) was observed for seed yield per plant, pod length, plant height, seed index and pods per plant, except for days to 50% flowering. These findings highlight the potential of these traits as selection criteria for improving mung bean productivity. Further, Field screening for MYMV classified the genotypes into three different response categories. Of the 302 genotypes, 25 were resistant (score 2) with a Percent Disease Index (PDI) ranging from 19.92% to 24.90%, 222 were moderately resistant (score 3) and 53 were moderately susceptible (score 4). The susceptible checks China Mung and LM-1668 recorded the highest PDI values of 73.04% and 78.02% respectively. The lowest PDI (19.92%) was recorded in GG-ABL-149, GG-ABL- 151, GG-ABL-196, GG-ABL-213, and

HUM 12 with seed yields per plant of 5.9, 5.3, 6.9, 6.6, and 5.4 g respectively. The identification of 25 MYMV-resistant genotypes alongside the observed genetic variability and heritability estimates, provides a valuable scientific basis forselecting promising parental materials and advancing resistance-oriented mung bean improvement. Integrating host-plant resistance into breeding programmes offers a promising approach to sustainable crop protection while supporting improved productivity and reducing vulnerability to MYMV disease.

Keywords: Mung bean, Mung bean Yellow Mosaic Virus, Genetic Variability, Heritability, Percent Disease Index, Host Plant Resistance

STUDIES ON THE BIOLOGICAL MANAGEMENT OF DRY ROOT ROT OF BLACK GRAM CAUSED BY *Rhizoctonia bataticola* (Taub.) Butler

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Abstract

Black gram (*Vigna mungo L. Hepper*) is an important pulse crop in India, valued for its protein-rich grain and its ability to improve soil fertility through nitrogen fixation. Several diseases limit its productivity. Dry root rot, caused by *Macrophomina phaseolina*, is one of the most destructive, particularly under moisture stress and high temperature. The pathogen is soil-borne and survives as microsclerotia, which makes chemical control difficult and costly, and harmful to the environment and beneficial soil microflora. Biological management using antagonistic microorganisms is therefore a sustainable alternative. Yield loss because of *R.bataticola* in black gram has not been estimated; however, investigators reported that infected plants showed a loss in grain yield and protein contents. Among the various diseases that infect black gram, dry root rot caused by *Rhizoctonia bataticola* (Taub.) Butler is a relatively emerging threat in South Asia, including India *R. bataticola* is a soil and seed borne pathogenic fungus and produces cushion shaped black sclerotia and disease severity is correlated with viable sclerotia present in the soil. High temperature and low soil moisture content are two factors that contribute to its prevalence. Many species of *Trichoderma* have been used as potent biocontrol agents for a variety of phytopathogenic fungi viz., *Sclerotium rolfsii, Rhizoctonia solani* and *Pythium spp.* The response of Trichoderma to the presence of a potential host includes production of antibiotic compounds, formation of specialized structures and degradation of the host's cell wall by secretion of hydrolytic enzymes followed by the assimilation of its cellular content. Competition and bio surfactant are the two important factors present in the antagonistic organism which are able to inhibit the pathogen.

Keywords: Black gram, *Rhizoctonia bataticola, Macrophomina phaseolina*.

DIVERSITY AND VARIABILITY OF *Rhizoctonia solani* ISOLATES ON SHEATH BLIGHT OF RICE

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Abstract

Rhizoctonia solani Kühn (teleomorph: *Thanatephorus cucumeris*) is the primary cause of rice sheath blight. The Anastomosis Group AG1-IA is the most common and destructive variant worldwide, causing typical aerial symptoms and severe yield losses ranging from 10% to 50% in rice-growing regions. It causes distinctive necrotic lesions on leaf sheaths and infects aerial plant components. Based on hyphal fusion compatibility, the species complex *R. solani* is separated into 14 different anastomosis groups (AG1 through AG14 and AGBI). Although AG1-IA predominates in rice, different AGs or intra-group variations can occasionally show varying degrees of cross-infectivity or varying degree of virulence. Rice-affecting isolates of *R. solani* exhibit notable variation in culture shape, growth rate, and color, ranging from dark brown to whitish-brown and yellowish-brown. The quantity, size (0.8 to 2.8 mm), texture (smooth vs. rough), and location (aerial surface vs. embedded in mycelium) of sclerotia produced by various variants/isolates vary greatly, from moderately virulent to extremely aggressive strains. Strains of *R. solani* isolated from various geographic locations exhibited varying degrees of aggressiveness and relative lesion height (RLH) on host types. Commercial rice cultivars usually lack complete immunity or single-gene vertical resistance against R. solani. Indica rice varieties express higher tolerance than japonica types and conferred major resistance against the pathogen.

Keywords: Rice sheath blight, *Rhizoctonia solani*, Anastomosis group, Relative lesion height.

SILKWORM PUPAL WASTE-DERIVED CHITOSAN AS A SUSTAINABLE BIOPESTICIDE: A REVIEW OF ANTIFUNGAL AND ANTIBACTERIAL APPLICATIONS

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Abstract

The growing concern over chemical pesticide residues, environmental pollution, and the development of pesticide-resistant pathogens has increased the need for sustainable crop protection strategies. In this context, silkworm pupal waste, a by-product of the silk industry, offers an opportunity to develop value-added biomaterials for agricultural applications. Chitosan, a biodegradable and biocompatible biopolymer, has gained considerable attention for its potential antifungal and antibacterial properties. Its production from silkworm pupal waste could support waste valorization while promoting environmentally responsible plant disease management. This review explores the potential of silkworm pupal waste-derived chitosan as a sustainable biopesticide, with particular emphasis on its antimicrobial mechanisms and applications in crop protection. Chitosan may inhibit microbial growth by interacting with negatively charged microbial cell surfaces, disrupting membrane integrity, altering cellular permeability, and interfering with essential metabolic processes. It may also stimulate plant defence responses, strengthen physical barriers, and help plants tolerate pathogen attacks. These properties suggest potential applications against fungal pathogens responsible for wilts, rots, and leaf diseases, as well as bacterial pathogens associated with important crop diseases. The effectiveness of chitosan depends on factors such as molecular weight, degree of deacetylation, concentration, formulation, and environmental conditions. Despite its promise, challenges related to extraction efficiency, product standardization, field performance, and economic feasibility require further investigation. Future research should focus on optimizing extraction methods, developing effective formulations, and validating efficacy through greenhouse and field trials. Overall, silkworm pupal waste-derived chitosan represents a promising approach to converting sericulture waste into a useful agricultural resource, contributing to circular bioeconomy principles and sustainable crop protection.

Keywords: Silkworm pupae, chitosan, biopesticide, antifungal activity, antibacterial activity, sustainable crop protection.

INNOVATIVE APPROACHES FOR ENHANCING AGRICULTURAL RESILIENCE, CROP HEALTH AND SUSTAINABLE PLANT PROTECTION

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Abstract

Agriculture plays a vital role in ensuring global food security, economic development, and environmental sustainability. However, agricultural production is increasingly threatened by climate change, unpredictable weather patterns, emerging insect pests, invasive species, plant diseases, soil degradation, and the excessive use of synthetic pesticides. Rising temperatures, altered rainfall patterns, and changing climatic conditions can influence insect population dynamics, pest distribution, reproductive behaviour, and the occurrence of disease outbreaks, thereby creating new challenges for crop protection. These issues emphasize the importance of developing resilient agricultural systems that can maintain productivity while minimizing environmental impacts. Integrated approaches involving sustainable crop production, ecological pest management, and innovative plant protection technologies are essential for addressing these challenges.

Integrated Pest Management (IPM) is an important strategy that combines cultural, mechanical, biological, physical, and chemical methods to maintain pest populations below economically damaging levels. Cultural practices such as crop rotation, intercropping, mixed cropping, field sanitation, trap cropping, and habitat manipulation help reduce pest establishment and improve agroecosystem stability. Biological control using predators, parasitoids, entomopathogenic fungi, bacteria, and viruses provides environmentally friendly alternatives to conventional chemical pesticides. The conservation and augmentation of natural enemies also play an important role in maintaining ecological balance and reducing pest outbreaks. Furthermore, botanical pesticides derived from neem, pongamia, and other plant sources offer potential alternatives for managing insect pests with reduced environmental impact. Recent advancements in agricultural biotechnology and nanotechnology have created new opportunities for sustainable crop protection. Nano-formulations, nano-based pesticide delivery systems, and microbial formulations can potentially improve the efficiency, stability, and targeted application of plant protection products.

Keywords: Agricultural resilience, sustainable agriculture, crop health, plant protection, integrated pest management, biological control, entomopathogens, botanical pesticides, nanotechnology, climate-smart agriculture, precision agriculture, pest surveillance, beneficial insects, biodiversity conservation, food security.

RESPONSE OF RICE TO DIFFERENT ZINC FORMULATIONS APPLIED THROUGH SOIL AND FOLIAGE

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Abstract

The field experiment was conducted at Experimental Farm in the Department of Agronomy, Annamalai University, Annamalai Nagar, Tamil Nadu, India during the Navarai season (January – April, 2024) to study the effect of different sources and methods of zinc application to augment the productivity and profitability of rice. The experimental design was a Randomized Block Design (RBD) with seven treatments were replicated thrice. Treatments comprised of T 1 – RDF, T 2 – RDF + soil application of ZnSO 4 12% EDTA @ 1.25 kg ha -1 , T 3 – RDF + soil application of zinc oxide suspension 39.5% w/w @ 750ml ha -1 , T 4 – RDF + soil application of ZnSO 4 monohydrate (Zn 33% and S 15%) @ 5 kg ha -1 , T 5 – RDF + foliar application of ZnSO 4 12% EDTA @ 0.15% at 30 and 60 DAT, T 6 – RDF + foliar application of zinc oxide suspension 39.5% w/w @ 2000 ppm at 30 and 60 DAT and T 7 -RDF + foliar application of ZnSO 4 monohydrate (Zn 33% and S 15%) @ 0.2% + 1% Urea at 30 and 60 DAT.Among the different treatments tested, at active tillering stage, (T 3) the application of 100% RDF combined with the soil application of zinc oxide suspension 39.5% w/w @ 750ml ha -1 recorded higher influence on the growth character viz., plant height, number of tillers hill -1 , leaf area index, root length, root volume and dry matter production of rice. However, application of 100% RDF along with the foliar application of zinc oxide suspension 39.5% w/w at 2000 ppm @ 30 and 60 DAT (T 6) proved their excellence by registering a remarkable influence on the growth characters at panicle initiation and harvest stages and the least values were recorded in (T 1) application of 100% RDF alone.

Keywords: Foliar application, soil application, zinc oxide, zinc sulphate monohydrate, zinc sulphate EDTA.

OPTIMIZING ORGANIC NUTRIENT MANAGEMENT FOR ENHANCED RHIZOSPHERE BIOLOGICAL ACTIVITY, ROOT DEVELOPMENT AND PRODUCTIVITY OF TRADITIONAL RICE VARIETIES UNDER RESILIENT PRODUCTION SYSTEMS

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Abstract

Traditional rice varieties represent valuable genetic resources for resilient agricultural systems, while organic nutrient management offers opportunities to improve crop productivity, root development and soil biological health. understanding the interactions between rice varieties, root characteristics and rhizosphere microbial activity is essential for developing effective nutrient management strategies that support crop health and agricultural resilience. recent research has highlighted the potential of vermicompost to improve rice productivity and soil microbial community composition (iqbal et al., 2024). furthermore, investigations into rice root-associated microbial communities have emphasized the importance of agricultural management practices in shaping rhizosphere microbial dynamics (zhu et al., 2025). a field experiment was conducted during the kuruvai season of 2025 at the experimental farm, faculty of agriculture, annamalai university, tamil nadu, to investigate the growth, root characteristics, rhizosphere microbial dynamics and productivity of traditional rice varieties under different organic nutrient management practices. the experiment was laid out in a split-plot design with three replications. four traditional rice varieties, namely aruvatham kuruvai, poongar, navara and ottu kichhili, were evaluated under five nutrient management treatments comprising farmyard manure, vermicompost, enriched farmyard manure, municipal compost and an absolute control. organic nutrient treatments were supplemented with 5% jeevamrutham. growth attributes, root characteristics, grain yield and rhizosphere microbial populations were assessed. among the evaluated treatment combinations, poongar supplied with vermicompost and jeevamrutham recorded the highest grain yield, representing an approximately 140% increase over the absolute control. this treatment combination also exhibited superior root development and enhanced rhizosphere biological activity. vermicompost-based nutrient management supported greater populations of bacteria, fungi and actinomycetes than the absolute control, highlighting the beneficial response of soil microbial communities to organic

nutrient inputs. the findings demonstrate the potential of integrating traditional rice varieties with organic nutrient management to improve crop productivity, root development and rhizosphere biological activity. the superior performance of poongar under vermicompost-based nutrient management emphasizes the importance of combining suitable varietal selection with biologically based nutrient management practices. this approach may contribute to improved soil biological health and resilient rice production systems. further investigations into pest and disease responses could establish the broader contribution of these practices to integrated plant protection and agricultural resilience.

Keywords: traditional rice; organic nutrient management; vermicompost; jeevamrutham; rhizosphere microbial dynamics; root development

ISOLATION, CHARACTERIZATION, FORMULATION OF *Pseudomonas plecoglossicida* FOR BIOPESTICIDE DEVELOPMENT

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Abstract

The growing demand for eco-friendly farming methods has led researchers to seek organic pesticides that can replace commonly used chemical agents. They isolated Pseudomonas plecoglossicida, a plant growth-promoting rhizobacterium (PGPR), and founded their sustainable biopesticide solutions on it.. The researchers used serial dilution to isolate the bacterium by culturing it on King's B agar and testing its biopesticide potential. The isolated bacterium underwent biochemical tests, which confirmed positive results for the catalase test and oxidase test, citrate test, and gelatin test, while showing negative results for the starch and MR-V tests. The positive results demonstrate that the bacterium exhibits non-fermentative metabolic patterns, which represent common traits of Pseudomonas plecoglossicida. The research results demonstrated that Pseudomonas plecoglossicida functions as an effective biocontrol agent for sustainable agriculture because it produces biocontrol agent characteristics through its enzyme production and pigment-based iron acquisition capabilities.

Keywords: *Pseudomonas plecoglossicida,* plant growth-promoting rhizobacteria (PGPR), biocontrol agent, biopesticide, sustainable agriculture, rhizosphere bacteria, biochemical.

ENZYME-BASED BIOPESTICIDES FOR SUSTAINABLE PLANT PROTECTION: MECHANISMS, FORMULATION STRATEGIES, AND FUTURE PERSPECTIVES

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Abstract

To protect crop form pest, chemical pesticides are used for several years. Due to the side-effects caused by the chemical fertilizer growers are considering enzymes as a gentler way to protect the crops against pest. Enzyme-based biopesticide work by disrupting the signals in cell (or) destroying the structural protein supporting the fungai, bacteria, insects, nematodes depend on to damage plants. Some of the enzymes, which plays major role against pests are chitinases, β-1,3-glucanases, proteases, lipases, cuticle-degrading enzymes, and quorum- quenching lactonases. People are using them in several ways either by purified or semi-purified proteins (or) as mixture that imitate biocontrol agents, as products that microbial inoculant secrete. This review is about how different enzyme class act on its target, how the enzymes are being sourced and produced, how the formulation is tackling the biggest flaw of the enzyme-it's instability. Also follows the delivery routes, the regulatory and market picture, and the gaps that still separate promising laboratory results from registered products. Different enzymes working together often achieve more than any single enzyme can do. Activity measured in the laboratory does not reliably predict what happens in the pest. And formulation and cost, rather than enzyme discovery, are what is now holding the field back.

Keywords: Biopesticides, Enzyme, Semi-purified proteins and Formulation

FROM MICROBIAL METABOLITES TO MOLECULAR INTERACTIONS: AN INTEGRATED APPROACH TO RICE BACTERIAL LEAF BLIGHT MANAGEMENT

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Abstract

Bacterial leaf blight (BLB), caused by *Xanthomonas oryzae pv. oryzae* (Xoo), is a major disease affecting rice production and highlights the need for sustainable disease-management strategies (Mansfield et al., 2012). Actinobacteria represent a promising source of bioactive metabolites with potential applications in plant disease management (Barka et al., 2016). This study investigated the antagonistic potential and metabolite profile of actinobacterial isolate AMGD-16 and explored the predicted interactions of selected metabolites with pathogen- associated proteins using computational approaches. Forty-five actinobacterial isolates collected from rice-growing regions of Karnataka, India, were screened against Xoo. The most effective isolate, identified as *Streptomyces ginkgonis* through 16S rRNA gene sequencing, produced an inhibition zone of 2.20 ± 0.06 cm. High-resolution liquid chromatography–mass spectrometry (HRLC–MS) profiling detected 1,141 distinct chemical entities, including putative antimicrobial metabolites such as lumichrome, fusidic acid, lividomycin B and manumycin. Seven Xoo-associated proteins were modelled and assessed for structural quality before molecular docking with selected metabolites. Lumichrome exhibited favourable predicted binding affinities across the seven targets, ranging from −6.9 to −9.6 kcal mol^{-1}, with the strongest predicted interaction observed with RpfF (−9.6 kcal mol^{-1}), followed by DnaA (−8.0 kcal mol^{-1}) and peptidyl deformylase (−7.6 kcal mol^{-1}). Furthermore, 100-ns molecular dynamics simulations of the peptidyl deformylase–lumichrome and PthXo1–lumichrome complexes indicated structural stability and favourable ligand interactions based on root-mean-square deviation, root-mean-square fluctuation, radius of gyration, solvent-accessible surface area and hydrogen-bond analyses. Overall, these findings highlight *S. ginkgonis* AMGD-16 as a potential source of bioactive metabolites and identify lumichrome as a candidate for further investigation against Xoo- associated targets. Experimental validation is necessary to establish the antimicrobial activity and practical applicability of these findings for sustainable BLB management.

Keywords: Actinobacteria; bacterial leaf blight; HRLC–MS; lumichrome; molecular docking; *Xanthomonas oryzae pv. Oryzae*.

INTEGRATED ZINC AND SILICON NUTRITION WITH SEAWEED EXTRACT FOR IMPROVING YIELD AND NUTRIENT UPTAKE IN TRANSPLANTED RICE

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Abstract

Meeting the growing demand for rice requires sustainable agronomic strategies that improve crop productivity and nutrient acquisition. Seaweed extracts have demonstrated potential to improve rice growth, yield and nutrient uptake [1], while combined zinc and silicon nutrition has been investigated for its effects on rice productivity [2]. This study evaluated the combined effects of micronutrient supplementation and biostimulant application on grain yield and zinc and silicon uptake in transplanted rice at the Experimental Farm, Department of Agronomy, Faculty of Agriculture, Annamalai University, Tamil Nadu, during the Kuruvai season (June–September 2024). A split-plot experiment comprising four main-plot treatments (control, zinc, silicon and zinc + silicon) and four subplot treatments (water spray control, humic acid, seaweed extract and vermiwash), with three replications, was conducted. The combined application of zinc sulphate @ 25 kg ha -1 and diatomaceous earth @ 50 kg ha -1 , along with foliar application of seaweed extract @ 0.3% at 20 and 40 days after transplanting, recorded the highest grain yield of 6,270 kg ha -1 , zinc uptake of 248.90 g ha -1 and silicon uptake of 138.90 kg ha -1 . These findings demonstrate the potential of integrated zinc and silicon nutrition coupled with seaweed extract application to enhance grain productivity and nutrient uptake, offering a promising approach for sustainable rice production.

Keywords: Transplanted rice, zinc nutrition, silicon nutrition, seaweed extract, grain yield, nutrient uptake.

INTEGRATED PHOSPHORUS MANAGEMENT WITH MICROBIAL INOCULANTS FOR SUSTAINABLE PRODUCTION AND PROFITABILITY OF IRRIGATED BLACKGRAM (*Vigna mungo* L.)

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Abstract

Efficient phosphorus (P) management is essential for improving pulse productivity and profitability, as phosphorus fixation in soil can limit its availability and constrain crop growth and yield. Phosphorus plays a vital role in plant growth, energy transfer and biological nitrogen fixation, making adequate P nutrition particularly important in leguminous crops (Khan et al., 2023). Integrating mineral phosphorus fertilizers with beneficial microbial inoculants offers a potential strategy to improve nutrient acquisition and crop performance. Phosphorus-solubilizing bacteria (PSB) enhance phosphorus availability by solubilizing less available soil phosphorus, while vesicular-arbuscular mycorrhizal (VAM) fungi improve nutrient acquisition through their symbiotic association with plant roots (Suthar and Dange, 2022). A field experiment was conducted from January to April 2025 at the Experimental Farm, Department of Agronomy, Faculty of Agriculture, Annamalai University, Chidambaram, to evaluate integrated phosphorus management strategies in irrigated blackgram (Vigna mungo L.). The experiment comprised twelve treatment combinations involving phosphorus application at 40 and 60 kg P_2O_5 ha -1 , in combination with PSB and VAM fungi through seed treatment and soil application. Treatments were arranged in a Randomized Block Design with three replications. Integrated phosphorus management significantly influenced growth attributes, including plant height, number of branches per plant, leaf area index and dry matter production, as well as yield attributes such as pods per plant, seeds per pod and test weight. Application of 60 kg P_2O_5 ha -1 combined with PSBand VAM fungi recorded the highest growth and yield performance. However, application of40 kg P_2O_5 ha -1 with the microbial inoculants achieved a comparable seed yield and the highest benefit–cost ratio. These findings highlight the potential of integrating mineral phosphorus fertilizers with microbial inoculants to improve blackgram productivity and profitability while supporting sustainable nutrient management in irrigated pulse-based cropping systems.

Keywords: Blackgram, phosphorus management, phosphorus-solubilizing bacteria, vesicular-arbuscular mycorrhizal fungi, integrated nutrient management, sustainable crop production.

EARLY DETECTION OF CROP HEAT STRESS USING DRONE-BASED THERMAL IMAGING

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Abstract

Rising temperatures and increasingly frequent heat events threaten crop growth, productivity and food security. Early identification of thermal stress can support timely agronomic interventions before visible symptoms become severe. Drone-based thermal infrared imaging offers a non-destructive,high-resolution approach for monitoring canopy temperature across fields and identifying spatial differences in crop water status. This review-based abstract synthesizes published research on unmanned aerial vehicle (UAV) thermal sensing, canopy-temperature extraction and the Crop Water Stress Index (CWSI), which is commonly used to interpret crop stress from thermal measurements. Thermal images provide detailed field-level information, while image-processing and canopy segmentation methods help distinguish crop foliage from exposed soil and other background features. Combining thermal information with multispectral data and machine-learning methods may further improve stress assessment and support precision irrigation decisions. However, reliable application depends on sensor calibration, weather and flight conditions, crop type, canopy structure, image-processing accuracy and validation against plant or field measurements. Thermal imaging should therefore be treated as a decision-support tool rather than a standalone diagnosis of heat stress. Future work should prioritize standardized data-collection protocols, robust segmentation, crop-specific validation and practical integration with irrigation management systems. Overall, UAV-based thermal imaging has strong potential to help agronomists identify spatial stress patterns, target field scouting and use water more efficiently under increasingly variable climatic conditions.

Keywords: UAV, thermal infrared imaging, crop heat stress, canopy temperature, Crop Water Stress Index, precision irrigation.

BIOCHEMICAL MECHANISMS AND DETERMINANTS OF HOST-PLANT RESISTANCE TO EGGPLANT SHOOT AND FRUIT BORER (*Leucinodes orbonalis* Guenée) IN BRINJAL (*Solanum melongena* L.)

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Abstract

To evaluate the biochemical basis of host-plant resistance against the brinjal shoot and fruit borer (*Leucinodes orbonalis guenée*), thirty eggplant hybrids alongside six cultivated varieties exhibiting varying levels of pest incidence were investigated. Quantitative analyses of primary biochemical constituents—specifically total phenols, polyphenol oxidase (PPO) activity, total sugars, and the glycoalkaloid solasodine—revealed distinct relationships with borer damage. Among the tested germplasm, the hybrids Sevathampatti local × Spiny local and Sevathampatti local × Settipulam local demonstrated superior host resistance, recording the lowest fruit infestation rate (14.68%) and achieving maximum crop yield (3.27 kg per plant). Correlation analyses established that fruit infestation was non-significantly positively correlated with calyx length (r = 0.314), whereas total yield per plant (r = -0.297), solasodine content (r = -0.170), and total phenol concentration (r = -0.572) exhibited significant negative correlations with fruit infestation2. Additionally, fruit infestation showed positive correlations with shoot infestation (r = 0.041), polyphenol oxidase (r = 0.011$), and total sugar levels ($r = 0.072).Association studies at both genotypic (r_g) and phenotypic (r_p) levels confirmed that total sugars were positively associated with fruit infestation percentage (r_g = 0.190; r_p = 0.049). Conversely, inverse associations at both genotypic and phenotypic levels were observed for total phenols (r_g = -0.399; r_p = -0.224), polyphenol oxidase (r_g = -0.120; r_p = -0.060), and solasodine (r_g = -0.209; r_p = -0.080).Consequently, crosses such as Manaparai local × Spiny local, Sevathampatti local × Spiny local, and Sevathampatti local × Settipulam local—which integrate elevated phenolic content, high PPO activity, low total sugars, reduced calyx length, minimal shoot and fruit damage, and superior yield potential—serve as valuable resistant parental combinations for future insect resistance breeding programs.

Keywords: Biophysical, biochemical, *Leucinodes orbonalis*, resistance

EXPLORING THE GENETIC VARIABILITY, HERITABILITY, GENE ACTION FOR YIELD RELATED TRAITS AND TO LCNDV RESISTANCE ON F 3 AND F 4 GENERATIONS OF CROSS DC 70 X DC 773 IN CUCUMBER (*Cucumis sativus* L.)

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Abstract

Cucumber is traditionally cultivated in India. It is recognised as a primary centre of origin for this vegetable crop, which is a part of the gourd family, Cucurbitaceae. In both F 3 and F 4 generations, percent disease index (PDI), fruit weight and vine length exhibited high heritability and genetic advance as percent of mean (GAM). Yield related traits viz., sex ratio, number of fruits per vine, yield per plant and vine length exhibited complementary gene action. Leptokurtic distribution in yield per plant and associated traits implied the involvement of few genes for genetic inheritance of the above traits. Significant positive associations were found between yield per plant and number of fruits per plant, fruit weight and number of branches per plant, suggesting potential early selection for these characters to enhance overall yield.

Keywords: PCV, GCV, Heritability, GAM, Skewness, Kurtosis, Gene action.

ASSESSMENT OF RHIZOSPHERE-DERIVED *Bacillus spp*. FOR THE BIOLOGICAL MANAGEMENT OF FUSARIUM WILT IN BRINJAL

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Abstract

Brinjal (*Solanum melongena* L.) is an economically significant vegetable cultivated across Asia, Africa, and the Mediterranean region. However, Fusarium wilt, caused by *Fusarium oxysporum f. sp. melongenae*, poses a serious threat to crop production, resulting in 10–90% disease severity and 20–30% plant mortality. Considering the environmental and health concerns associated with chemical fungicides and the development of pathogen resistance, this study evaluated rhizosphere bacteria as potential eco-friendly biocontrol agents.The pathogen was isolated from diseased brinjal plants collected from Adhiparasakthi Horticultural College and designated FIHC-1. Its morphological and cultural characteristics, including mycelial growth, colony pigmentation, and macroconidial, microconidial, and chlamydospore morphology, were examined. Five Bacillus isolates (HCBI-01 to HCBI-05) were obtained from the rhizosphere soils of healthy mango, chilli, sesame, groundnut, and brinjal plants. The isolates were characterized through colony morphology and biochemical tests, including Gram staining, catalase activity, KOH solubility, and growth at 45°C and 4°C, confirming their Gram-positive, thermotolerant, and non-psychrophilic nature. Antagonistic activity against *F. oxysporum f. sp. melongenae* was assessed in vitro using dual-culture and pair-plate techniques at 3, 5, and 7 days after inoculation (DAI). All five isolates significantly inhibited pathogen growth compared with the control. HCBI-05 exhibited the highest inhibition, reaching 59.26% in dual culture and 58.52% in the pair-plate assay at 7 DAI, whereas HCBI-03 was the least effective. These results identify Bacillus spp., particularly HCBI-05, as promising candidates for sustainable Fusarium wilt management in brinjal.

Keywords: Brinjal, rhizosphere bacteria, Bacillus spp., Fusarium wilt, biological control.

EMERGING ECO-FRIENDLY STRATEGIES FOR SUSTAINABLE MANAGEMENT OF SOIL-BORNE PLANT DISEASES: STRENGTHENING CROP HEALTH AND AGRICULTURAL RESILIENCE

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Abstract

Soil-borne plant diseases are a major constraint on agricultural productivity, crop health, and sustainable food production. The increasing occurrence of fungal pathogens and the excessive use of chemical fungicides highlight the need for environmentally friendly and resilient plant disease management strategies. This review explores emerging approaches for managing soil-borne plant diseases, including biological control agents, microbial consortia, organic amendments, resistant crop varieties, and integrated disease management. Particular attention is given to beneficial microorganisms such as Trichoderma, Bacillus, and Pseudomonas, which suppress plant pathogens, improve soil health, and support plant growth. The potential integration of these biological approaches with modern technologies, including precision agriculture and molecular diagnostic tools, is also discussed. Combining ecological practices with innovative disease management methods can reduce dependence on chemical pesticides, improve soil microbial diversity, and enhance crop resilience under changing environmental conditions. This review highlights the importance of integrating sustainable biological solutions into agricultural systems to promote long-term crop health, environmental protection, and resilient food production.

Keywords: Soil-borne diseases, biological control, sustainable agriculture, crop health, microbial diversity, integrated disease management.

RNA-BASED TECHNOLOGIES FOR SUSTAINABLE MANAGEMENT OF PLANT DISEASES: A NEW GENERATION APPROACH TO CROP PROTECTION

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Abstract

Sustainable crop production requires effective disease management strategies that can reduce dependence on conventional chemical pesticides while maintaining crop productivity. Recent advances in agricultural biotechnology have introduced RNA-based technologies as promising tools for the precise and environmentally friendly management of plant diseases. RNA interference (RNAi) is a natural biological mechanism in which small RNA molecules regulate gene expression by targeting specific messenger RNAs. This principle has been explored for suppressing essential genes of plant pathogens and reducing disease development. Spray-induced gene silencing (SIGS) is an emerging approach in which externally applied double-stranded. RNA can trigger gene silencing in targeted pathogens without requiring permanent genetic modification of the crop. RNA-based strategies have been investigated against fungal, bacterial and viral pathogens, demonstrating their potential for pathogen-specific disease suppression. Compared with conventional pesticides, these approaches can provide greater target specificity and may reduce undesirable effects on beneficial organisms and the environment. However, challenges such as RNA stability, efficient delivery, cost-effective production and field-level application need further attention. Integration of RNA-based technologies with biological control, resistant varieties and other components of integrated disease management could strengthen sustainable crop protection. Thus, RNA-based disease management represents an innovative and promising direction for achieving safer, precise and sustainable crop production.

Keywords: RNA interference, Spray-induced gene silencing, Plant pathogens, Sustainable crop protection, RNA-based technology, Disease management, Agricultural biotechnology

EXPLORATION OF ENDOPHYTIC MICROBES ASSOCIATED WITH TRADITIONAL RICE LANDRACES FOR THE BIOCONTROL OF SEED-BORNE PATHOGENS

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Abstract

Seed-borne fungal pathogens adversely affect rice seed health, germination, seedling vigour and crop establishment, highlighting the need for sustainable alternatives to chemical seed treatments. This study investigated the antagonistic potential of endophytic microbes associated with traditional rice landraces against major seed-borne fungal pathogens. Four predominant pathogens, namely *Sarocladium oryzae, Curvularia lunata, Fusarium sp.* and *Bipolaris oryzae*, were isolated from infected rice seeds collected from major rice-growing regions of Tamil Nadu, with seed infection incidence ranging from 26.73% to 42.56%. Endophytic microbial isolates associated with 13 traditional rice landraces were screened for their antagonistic and plant growth-promoting activities. Among the isolates, the bacterial strains EPT1 and EPKu1 exhibited the highest antagonistic activity, inhibiting the mycelial growth of the test pathogens by 45–64%. Seedling vigour assessments further identified EPKu1 (vigour index: 5,500) and EPT1 (vigour index: 5,300) as promising plant growth- promoting isolates. Molecular identification based on 16S rRNA gene sequencing identified EPKu1 and EPT1 as Bacillus megaterium and Bacillus subtilis, respectively. In pot culture experiments, seed treatment with the bacterial bioformulation at 10 mL kg^{-1} seed resulted in 100% germination, a maximum seedling vigour index of 3,700 and 52.36% disease suppression, whereas carbendazim treatment recorded 88.95% disease suppression. The findings highlight the potential of beneficial endophytic bacteria associated with traditional rice landraces as promising candidates for developing eco-friendly microbial seed treatments against seed-borne fungal pathogens. Further validation under field conditions and assessment of formulation stability are warranted to establish their practical applicability in sustainable rice production.

Keywords: Traditional rice landraces, endophytic bacteria, seed-borne pathogens, *Bacillus* spp. biological control, seed health.

DEVELOPMENT AND FUNCTIONAL EVALUATION OF A *Bacillus thuringiensis*-CHITOSAN NANOCOMPOSITE FOR UV PHOTOPROTECTION, GROWTH PROMOTION, AND INSECTICIDAL ACTIVITY

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Abstract

Bacillus thuringiensis (Bt) is an important microbial biopesticide; however, its field efficacy is often limited by ultraviolet (UV) radiation, environmental instability, and reduced persistence under field conditions. This study aimed to develop and evaluate chitosan-based Bt nanocomposites (Bt-ChNCs) to enhance UV photoprotection, biological performance, and crop-protection potential. Bt spores were encapsulated in chitosan nanoparticles and characterized using dynamic light scattering (DLS), zeta-potential analysis, Fourier-transform infrared (FTIR) spectroscopy, energy-dispersive X-ray spectroscopy (EDS), X-ray diffraction (XRD), and field-emission scanning electron microscopy (FE-SEM). The chitosan nanoparticles exhibited an average particle size of approximately 99 nm, while the Bt-ChNP formulation displayed changes in surface charge and structural characteristics consistent with nanocomposite formation. Under UV exposure, the encapsulated formulation exhibited greater retention of spore viability and protein content than unencapsulated Bt, suggesting enhanced protection against UV-induced degradation. Seed-treatment assays further demonstrated improvements in seed germination and seedling development, with selected Bt- ChNP treatments promoting shoot and root growth. Insecticidal bioassays against the lepidopteran pests, such as *Spodoptera litura, Plutella xylostella, Spodoptera frugiperda*, and *Helicoverpa armigera*, demonstrated retained insecticidal activity, with larval mortality varying according to treatment and dose. Microscopic assessments and field observations further supported the biological efficacy of the formulations, while multilocation field trials involving Bt-ChNP microemulsions indicated reductions in larval abundance and crop damage. Collectively, these findings suggest that chitosan-based nanoencapsulation can improve the UV stability of Bt preparations while preserving their insecticidal potential and supporting plant growth. The developed Bt-ChNP formulations therefore represent a promising approach for advancing more stable and environmentally compatible microbial biopesticides for sustainable crop protection.

Keywords: *Bacillus thuringiensis*, UV protection, Bt biopesticide, encapsulation

CHARACTERIZATION OF GENETIC VARIABILITY AND PERFORMANCE AMONG CHILLI (*Capsicum annuum* L.) GENOTYPES

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Abstract

Eight diverse genotypes of chilli (Capsicum annuum L.) were evaluated under open field conditions during the Kharif 2015 season in a Randomized Block Design (RBD) with three replications to assess the extent of genetic variability, heritability, and genetic advance among yield and yield-related traits. Analysis of variance indicated highly significant differences among genotypes for all the characters studied, signifying the presence of substantial genetic variability in the material. High genotypic coefficients of variation (GCV) were observed for flowers per branch (21.59%), clusters per plant (19.26%), and stem diameter (15.49%), while high phenotypic coefficients of variation (PCV) were recorded for flowers per branch (26.70%), fruits per branch (24.44%), clusters per plant (24.04%), and stem diameter (19.26%). High broad-sense heritability estimates coupled with high genetic advance were obtained for flowers per branch (65%), fruits per plant (64%), clusters per plant (64%), stem diameter (65%), plant weight (59%), and days to 50% flowering (50%). These results indicate that additive gene effects predominantly govern these traits, suggesting that substantial improvement through selection would be highly effective.

Keywords: Genotypes, Chilli, Kharif, Analysis, Randomized Block Design (RBD)

INTEGRATED RESILIENCE STRATEGIES FOR SUSTAINABLE PLANT PROTECTION IN FRUIT CROPS

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Abstract

Fruit crops are increasingly threatened by insect pests, diseases, climate variability and the emergence of pesticide resistance, resulting in reduced productivity, fruit quality and orchard sustainability. Conventional plant protection approaches that rely heavily on chemical pesticides often provide short term control but may adversely affect beneficial organisms, environmental health and long term production stability. Integrated resilience strategies offer a holistic approach to strengthening the capacity of fruit crops and orchard ecosystems to prevent, withstand and recover from biotic and abiotic stresses. These strategies integrate resistant cultivars and rootstocks, healthy planting material, cultural practices, orchard sanitation, biological control, pest surveillance, early-warning systems and need-based chemical interventions. Soil health management, efficient irrigation, canopy management, biodiversity conservation and climate-smart horticultural practices further enhance crop vigour and resilience. In major fruit crops such as mango, guava, banana, citrus, pomegranate and dragon fruit, combining preventive measures with biological and ecological approaches can contribute to the sustainable management of important pests and diseases. The integration of digital monitoring tools, weather based disease forecasting and decision-support systems can improve the timeliness and precision of plant protection interventions. Furthermore, coordinated research, farmer education and location-specific validation are essential for the successful implementation of these strategies. An integrated resilience-based framework shifts plant protection from reactive pest suppression towards proactive ecosystem management, supporting reduced pesticide dependence, improved resource use efficiency, stable fruit production and long-term orchard sustainability. This approach provides a foundation for developing climate-resilient, environmentally responsible and economically viable fruit production systems.

Keywords: Fruit crops, IPM, biological control, pest surveillance, ecosystem health.

ISOLATION AND IDENTIFICATION OF LOCAL *Bacillus thuringiensis* STRAINS FOR DEVELOPMENT OF SUSTAINABLE BIOPESTICIDE AGAINST *Tribolium castaneum*

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Abstract

The use of insect pathogens is a possible alternative to chemical insecticides for insect pest control owing to their relative specificity and lower environmental impact. In the present study, *Bacillus thuringiensis* (Bt) strains were isolated from samples collected from different habitats, *viz.,* warehouse, processing unit and insects from different locations in the Vidarbha region of Maharashtra. The isolated bacteria were identified on the basis of colony morphology, Gram staining, Green malachite staining, Amido black staining and presence of parasporal crystals by phase contrast microscopy (1000x). Acetone-precipitated spore crystal complex of 22 native Bt isolates as well as the reference strain, *viz., Bt tolworthi,* was prepared to evaluate the insecticidal activity. These isolates, along with the reference strain, will be screened for their toxicity against neonates and adults of the red flour beetle (*Tribolium castaneum)* by the diet overlay method at two concentrations, i.e., 10 and 100 µg/g of diet. The expected outcome of this study will be the development of a sustainable biopesticide formulation for the control of *T. castaneum* using local Bt isolates.

Keywords: Bt isolates, red flour beetle, *Tribolium castaneum,* Bt biopesticide

SCREENING OF CASTOR (*Ricinus communis* L.) GENOTYPES FOR RESISTANCE TO WHITEFLY (*Trialeurodes ricini* M.)

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Abstract

Castor (*Ricinus communis* L.) is an important industrial oilseed crop whose productivity is constrained by the castor whitefly, *Trialeurodes ricini* (Misra, 1924), a major sucking pest causing significant yield losses. Host plant resistance offers an economical, environmentally sustainable, and effective strategy for whitefly management. This study aimed to screen castor genotypes for resistance to *T. ricini* under natural field infestation. Twenty-five castor genotypes representing diverse genetic backgrounds were evaluated during the rabi season of 2025-2026 at the Tapioca and Castor Research Station (TCRS), Yethapur, Tamil Nadu, India, in a randomized complete block design (RCBD) with three replications. *T. ricini* infestation was assessed at 60 days after sowing by recording the number of nymphs and pupae per leaf, and genotypes were classified using the standard 0-5 whitefly damage rating scale. Significant variation in whitefly infestation was observed among the evaluated genotypes (P < 0.001), with whitefly populations ranging from 0.55 to 170.67 nymphs and pupae per leaf. JP 65, DPC 16, DPC 9, and DPC 17 consistently recorded the lowest infestation and were identified as the most resistant genotypes, whereas the susceptible check DCH 519 exhibited the highest infestation. *T. ricini* infestation increased progressively with bloom intensity, with zero- and single-bloom genotypes recording substantially lower infestations than double- and triple-bloom genotypes, demonstrating the usefulness of bloom as a rapid phenotypic marker for preliminary resistance screening. The identified resistant genotypes provide valuable donor sources for developing whitefly-resistant castor cultivars and can be effectively utilized in resistance breeding programmes to support sustainable whitefly management.

Keywords: Castor, *Ricinus communis*, *Trialeurodes ricini*, Host Plant Resistance (HPR), genotype screening, bloom.

FIELD EVALUATION OF SEAWEED EXTRACTS AGAINST RED SPIDER MITES (*Tetranychus urticae* Koch.) IN OKRA

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Abstract

Okra, *Abelmoschus esculentus* (L.) Moench, popularly known as bhendi or lady's finger is an important vegetable crop cultivated in India. The crop is affected by several pests among which red spider mite *Tetranychus urticae* (Koch.) causing significant damage to the crop particularly during summer season even under drought conditions. The excessive use of synthetic chemical pesticides against mite resulted in severe ecological and environmental problems including insecticide resistance, resurgence of secondary pests and the destruction of natural enemies. In this context seaweed extracts are the promising organic biostimulants have emerged as alternative for sustainable crop protection owing to their bioactive compounds and potential to enhance plant defence mechanisms. The present investigation was undertaken to evaluate the field efficacy of powdered form of seaweed extracts *viz*., *Kappaphycus alvarezii*, *Sargassum wightii* and *Ascophyllum nodosum* at 5 and 10 per cent concentrations compared with untreated control against red spider mite in okra. The first foliar spray was applied 20 days after sowing, followed by a second spray and third spray at a 15 days interval. Observation on mite population was observed on 1, 3, 5 and 7 days after spraying and expressed as no. of mites per cm^2/ 3 leaves. Among the different treatments, *Sargassum wightii* extracts at 10 per cent concentration recorded the highest reduction in mite population of 88.42 per cent over the untreated control after second spray. The 5 per cent concentration of *S. wightii* recorded a mean mite population of 8.50 mites per three leaves, *Corresponding to 84.53 per cent reduction over the untreated control. *Kappaphycus alvarezii* extracts at 10 per cent concentration recorded a mean population of 6.00 mites per three leaves with 65.05 per cent reduction over the control. There was a reduction in mite population was observed on the fifth day after the first spray. The results indicate that seaweed extracts, particularly *S. wightii* and *K. alvarezii*, have potential for suppressing red spider mite populations in okra under field conditions. The present

study concluded that the foliar application of *Sargassum wightii* at 10 per cent concentration is an effective and environmental strategy to control the mite population in okra. Further investigations are needed to validate its consistency across seasons and effects on natural enemies and large scale adoption by the farmers to establish their suitability as components of integrated pest management.

Keywords: Okra, red spider mite, *Tetranychus urticae*, seaweed extract, *Sargassum wightii*, *Kappaphycus alvarezii*, sustainable pest management.

NANO-ENABLED TOMATO PRODUCTION: ADVANCING CLIMATE RESILIENCE, NUTRIENT-USE EFFICIENCY AND SUSTAINABLE PLANT PROTECTION

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Abstract

Tomato (*Solanum lycopersicum* L.) is one of the most economically important vegetable crops worldwide; however, its productivity and quality are increasingly threatened by climate variability, nutrient imbalances, and the incidence of insect pests and diseases. Nanotechnology offers promising opportunities to address these challenges through precision nutrient delivery, improved stress tolerance, and sustainable crop protection. Nanomaterials, including zinc oxide, silicon dioxide, titanium dioxide, and nanoformulations of essential nutrients, have demonstrated potential to improve nutrient availability, photosynthetic efficiency, antioxidant defence, and plant growth when applied at appropriate concentrations. Nano-enabled nutrient delivery systems can enhance nutrient-use efficiency by improving the controlled release, absorption, and utilization of essential elements, potentially reducing nutrient losses and environmental contamination. Furthermore, certain nanomaterials may strengthen tomato plants' tolerance to abiotic stresses such as drought, salinity, and high temperature by modulating osmotic adjustment, reactive oxygen species scavenging, and physiological responses. In plant protection, nanoformulations of botanical compounds, essential oils, and selected antimicrobial agents offer opportunities for targeted pest and disease management, improved formulation stability, and reduced dependence on conventional pesticides. Nevertheless, the effectiveness of these technologies depends on nanoparticle composition, size, concentration, application method, soil properties, and environmental conditions. Potential risks associated with nanoparticle accumulation, phytotoxicity, soil microbial communities, and food-chain exposure must also be carefully evaluated. Therefore, integrating nanotechnology with precision fertigation, integrated pest management, and climate-smart cultivation practices could provide a promising pathway towards resilient and resource-efficient tomato production. Future research should prioritize long-term field validation, residue assessment, environmental safety, cost-effectiveness, and standardized application

protocols to ensure the responsible adoption of nano-enabled technologies. Overall, nanotechnology represents a promising tool for advancing sustainable tomato production by integrating climate resilience, nutrient-use efficiency, and environmentally responsible plant protection.

Keywords: Tomato; nanotechnology; climate resilience; nutrient-use efficiency; sustainable plant protection.

A SCIENTOMETRIC ANALYSIS OF CRISPR RESEARCH IN AGRICULTURAL AND BIOLOGICAL SCIENCES: KNOWLEDGE STRUCTURE, TRENDS AND VISUALIZATION (2016–2025)

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Abstract

This study presents a bibliometric analysis of CRISPR research in the fields of agricultural and biological sciences during the period 2016–2025. The study uses bibliographic data retrieved from the Scopus database using the search terms "CRISPR" and "Clustered Regularly Interspaced Short Palindromic Repeats," with the subject area restricted to Agricultural and Biological Sciences. The analysis examines publication growth, open-access patterns, document types, leading authors, source titles, keywords, institutions, funding agencies, and countries. The results indicate a substantial increase in CRISPR-related research output, with publications rising from 285 in 2016 to 3,145 in 2025 in the displayed dataset. Agricultural and Biological Sciences was the leading subject area, while genetics, CRISPR-Cas systems, gene editing, metabolism, and plant-related research were prominent themes. China, the United States, and India were among the leading contributing countries. The findings demonstrate the rapid expansion and increasing interdisciplinary nature of CRISPR research and highlight its importance for crop improvement, plant biotechnology, genetic engineering, and agricultural innovation.

Keywords: CRISPR-Cas, Gene Editing, Bibliometric Analysis; Agricultural Sciences, Science Mapping.

RESILIENCE STRATEGIES FOR SUSTAINABLE AGRICULTURE, CROP HEALTH AND PLANT PROTECTION

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Abstract

Agricultural systems worldwide are under mounting pressure from climate variability, emerging pests and pathogens, soil degradation, and the growing need to reduce dependence on synthetic agrochemicals. Building resilience, defined as the capacity of cropping systems to absorb stress, recover from disturbance, and maintain productivity over time, has therefore become central to sustainable agriculture. This paper reviews integrated strategies that strengthen crop health and plant protection while safeguarding environmental and socio-economic sustainability. Key approaches discussed include the development and deployment of resistant and climate-adapted cultivars, diversification through crop rotation, intercropping, and agroecological design, and soil health management using organic amendments, conservation tillage, and beneficial microbiomes. Integrated pest management (IPM) is examined as a core framework, combining biological control agents, biopesticides, cultural practices, and judicious chemical use guided by monitoring and threshold-based decision-making. The role of digital and precision technologies, such as remote sensing, early-warning and disease-forecasting models, and decision-support tools, in enabling timely and targeted interventions is also highlighted. Finally, the paper considers enabling factors, including farmer knowledge-sharing, extension services, supportive policy, and market incentives, that determine whether resilient practices are adopted at scale. Together, these strategies offer a pathway toward productive, ecologically balanced, and adaptable farming systems that protect crops while conserving natural resources for future generations.

Keywords: agricultural resilience, sustainable agriculture, crop health, plant protection, integrated pest management, climate adaptation, soil health, biological control

LOW-COST ACOUSTIC SENSOR-BASED DETECTION OF HIDDEN INSECT INFESTATION IN STORED AGRICULTURAL GRAINS

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Abstract

Hidden insect infestation in stored agricultural grains is a major post-harvest challenge because larvae and adults may develop inside kernels before visible damage becomes apparent. Delayed detection can contribute to grain-quality deterioration, weight loss, reduced market value and increased reliance on chemical fumigation. This proposed study explores a low-cost, non-destructive acoustic sensing approach for the early detection of insect activity in stored cereals and pulses. A microphone or contact-based acoustic sensor could be used to record insect-generated sounds within grain samples, while signal-processing methods would examine relevant acoustic features and distinguish potential insect activity from background noise. The approach would be evaluated using grain samples with independently verified infestation status, including uninfested controls and, where feasible, samples representing different infestation levels. Performance could be assessed through detection accuracy, sensitivity, specificity and false-positive rates, while considering factors such as grain type, storage conditions, sensor placement and ambient noise. Potential target commodities include rice, wheat, maize and pulses such as chickpea and green gram, with pest species selected according to local availability and experimental facilities. The study aims to assess whether an affordable acoustic monitoring system could support earlier pest detection and more timely, targeted storage management. By reducing dependence on visual inspection alone, this approach may contribute to improved post-harvest monitoring and sustainable stored-product pest management. As this is a proposed research framework, its practical value would need to be established through controlled experiments and validation under realistic storage conditions.

Keywords: Acoustic sensing, stored-grain insects, sensor technology, sustainable crop protection.

ADVANCES IN SEED QUALITY ENHANCEMENT, SEED HEALTH AND SUSTAINABLE CROP PRODUCTION

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Abstract

Seed quality enhancement and seed health management are fundamental components of sustainable crop production, contributing to improved crop establishment, higher productivity, efficient resource utilization, and long-term agricultural resilience. High-quality seeds possess superior genetic and physical purity, physiological vigour, viability, and freedom from seed-borne pathogens. However, climate change, fluctuating environmental conditions, emerging seed-borne diseases, and the increasing demand for quality food production present significant challenges to maintaining seed quality. Advances in seed science and technology offer innovative approaches to overcome these challenges through improved seed production practices, precision seed processing, advanced seed testing, seed enhancement treatments, and sustainable storage systems. Modern seed enhancement technologies, including seed priming, seed coating, seed pelleting, biopriming, and the application of beneficial microorganisms, can improve germination, seedling establishment, nutrient acquisition, and tolerance to environmental stresses. Seed health management has also advanced through molecular diagnostic tools, pathogen detection techniques, biological seed treatments, and integrated disease management strategies. These approaches facilitate early identification and effective management of seed-borne pathogens while reducing excessive dependence on chemical seed protectants. Furthermore, advanced seed processing equipment, optical sorting, digital imaging, and automated quality assessment systems enable the identification and removal of damaged, immature, and infected seeds, thereby improving seed lot uniformity and planting value. Sustainable seed storage technologies, including moisture-proof packaging, temperature and humidity management, and improved storage structures, help preserve seed viability and vigour during prolonged storage. The integration of these technologies with climate-resilient crop varieties, quality seed certification, and farmer-oriented seed delivery systems strengthens the availability of reliable planting materials. Seed science and technology also contribute to sustainable agriculture by supporting reduced input losses, improved crop establishment,

efficient nutrient management, and environmentally responsible production practices. Integrating seed quality enhancement, seed health management, and precision seed technologies can therefore improve agricultural productivity while conserving natural resources. Future progress will depend on making advanced seed technologies accessible, affordable, and adaptable to diverse farming systems, particularly in developing countries where quality seed availability remains a major constraint.

Keywords: Seed quality enhancement, Seed health management, Seed priming, Seed-borne pathogens, Sustainable crop production.

ORGANIC LEAF EXTRACT FORMULATION AS A TRADITIONAL STRATEGY FOR SUSTAINABLE CROP PROTECTION

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Abstract

The increasing need for sustainable agricultural practices has encouraged the exploration of traditional, locally available resources for crop health management and plant protection. An indigenous organic leaf extract formulation practiced by Mr. Vadivelu, an organic farmer from Othivakkam, Thirukazhukundram, Chengalpattu district, Tamil Nadu, and District Farmers' Association Leader, was documented as a farmer-based approach to crop protection. The formulation is traditionally used for managing sucking pests, caterpillars, viral disease symptoms and yellowing in various crops. The preparation involves mixing 15 litres of cow urine, 15 litres of cow dung, 50 litres of water and 0.5 kg each of 84 different types of leaves in a 200-litre barrel. The mixture is allowed to ferment for 40 days, with daily stirring beginning on the 11th day. On completion of the fermentation period, the extract is filtered and stored for application. The recommended dilution is one litre of extract in 10 litres of water, with application at 15-day intervals under severe pest infestation, as practised by the farmer. The suggested application stages include one-month-old paddy, jasmine before bud formation, and bhendi and brinjal before flower initiation and after flowering. This farmer-documented practice highlights the potential role of indigenous knowledge, locally available biological resources and low-cost formulations in sustainable crop protection. Further scientific validation is required to identify the plant species used, assess efficacy against specific pests and diseases, establish crop safety, and standardise preparation and application protocols. Documenting and evaluating such practices may contribute to the development of locally adaptable and resilient crop health management strategies.

Keywords: Organic leaf extract, indigenous technical knowledge, sustainable agriculture, crop protection, traditional formulation, integrated pest management.

PHYTOMELATONIN ENHANCES TOMATO ADAPTATION TO ALKALINITY STRESS

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Abstract

This study investigated the effectiveness of exogenous phytomelatonin in alleviating alkalinity stress in tomato (*Solanum lycopersicum* L.) cv. PKM 1. A pot culture experiment was conducted under experimentally induced alkalinity stress using 40 mM Na_2CO_3, with foliar application of phytomelatonin at 20, 40, 60, 80, 100, 120 and 140 µM, together with an absolute control and an alkalinity-stressed control. The study was designed to identify concentration-dependent responses across growth, water status, photosynthetic performance, osmotic adjustment, lipid peroxidation and antioxidant enzyme activities. Among the tested concentrations, 40 µM phytomelatonin produced the most consistent improvement in growth and physiological performance, recording plant height (78.7 cm), root length (24.20 cm), total leaf area (291.87 cm^2 $plant^{-1}$) and total dry matter production (98.4 g $plant^{-1}$). Relative water content (65.3%), chlorophyll stability index (61.8%), photosynthetic rate (28.1 µmol CO_2 m^{-2} s^{-1}), transpiration rate (9.9 mmol H_2O m^{-2} s^{-1}) and SPAD chlorophyll index (31.90) were also substantially improved compared with the stressed control. Phytomelatonin increased soluble protein and proline contents, with values of 9.52 mg g^{-1} and 342.45 mg g^{-1} fresh weight, respectively, at 40 µM, while reducing malondialdehyde (MDA) content to 20.7 nmol FW^{-1}. Antioxidant responses were concentration dependent: peroxidase, ascorbate peroxidase, polyphenol oxidase and superoxide dismutase activities were enhanced by melatonin, with the highest or near-highest responses generally observed at 40–140 µM depending on the enzyme. In contrast, catalase activity decreased in melatonin-treated plants relative to the stressed control, indicating that antioxidant regulation was enzyme specific rather than uniformly stimulatory. Overall, the results show that phytomelatonin improved tomato performance under alkalinity stress through coordinated effects on water relations, photosynthetic function, osmotic adjustment, membrane protection and antioxidant metabolism. Among the concentrations tested, 40 µM was the most effective overall treatment.

Keywords: Alkalinity stress; Tomato; Phytomelatonin; Photosynthetic efficiency; Osmotic adjustment; Antioxidant enzymes

CITRUS CANKER: PATHOGEN BIOLOGY, DETECTION AND GENOME-EDITING STRATEGIES FOR SUSTAINABLE MANAGEMENT

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Abstract

Citrus canker, caused by *Xanthomonas citri subsp. citri* (Xcc), is one of the most damaging bacterial diseases of citrus worldwide. The Asiatic form (type A) is the most destructive and infects most commercial cultivars, although susceptibility varies among species. Infection produces necrotic lesions on leaves, stems, and fruit, causing premature fruit drop, reduced fruit quality, and yield loss, and it restricts international trade in fresh fruit and planting material. No curative treatment exists. This review synthesizes current knowledge of the pathogen's taxonomy, biology, and epidemiology, detection methods, including PCR/qPCR, LAMP, and field-deployable diagnostics, the molecular basis of host susceptibility and the strengths and limitations of existing control measures. It also evaluates emerging biotechnological approaches for building durable resistance. Current management relies on quarantine and exclusion, copper- based bactericides, and integrated cultural practices, which are only partially effective and costly to sustain. Editing of host susceptibility genes, notably CsLOB1, the target of the Xcc effector PthA4, and CsDMR6, confers resistance to canker, and transgene-free CRISPR/Cas approaches may ease regulatory and public-acceptance barriers. Challenges remain, including Xcc strain diversity, the need to combine canker resistance with resistance to Huanglongbing (HLB, or citrus greening), and the long path from gene editing to field-grown cultivars. Integrating surveillance, quarantine, and targeted genome editing offers the most promising route to sustainable management. Future work should prioritize multi-strain resistance, trait stacking, and field evaluation of edited cultivars.

Keywords: *Xanthomonas citri subsp. citri*, Asiatic citrus canker, pathogen detection, CsLOB1, CRISPR/Cas, and integrated management.

CROP IMPROVEMENT IN SORGHUM (*Sorghum bicolor* (L.) Moench) FOR TOLERANCE TO FALL ARMYWORM (*Spodoptera frugiperda*)

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Abstract

Fall armyworm (*Spodoptera frugiperda*), an invasive and highly destructive lepidopteran pest, has emerged as a major threat to sorghum production, particularly during the early vegetative stages. The larvae primarily feed on young leaves, causing characteristic leaf damage, whorl injury, and reduced crop growth. Severe infestations may result in substantial yield losses, depending on pest population, crop growth stage, environmental conditions, and he susceptibility of the cultivated genotype. Although chemical insecticides and integrated pest management practices are commonly employed, developing resistant or tolerant sorghum cultivars offers a sustainable, economical, and environmentally sound approach to fall armyworm management. This review examines the current status and prospects of sorghum improvement for fall armyworm tolerance, with emphasis on genetic variability, host plant resistance mechanisms, and breeding strategies. The major resistance mechanisms include antixenosis, which reduces pest preference for oviposition and feeding; antibiosis, which adversely affects larval survival, development, and reproduction; and tolerance, which enables plants to maintain growth and yield despite insect injury. Morphological, biochemical, and molecular traits associated with resistance, including leaf toughness, trichome characteristics, epicuticular wax, nutritional composition, and defence-related metabolites, are discussed as potential selection criteria. The review also highlights their importance of screening diverse sorghum germplasm, landraces, breeding lines, and wild relatives under controlled and field conditions to identify promising sources of resistance. Conventional breeding, recurrent selection, marker-assisted selection, genomic approaches, and the integration of resistant cultivars with biological control and other integrated pest management strategies are considered for accelerating the development of improved sorghum varieties. Particular attention is given to the need for reliable screening protocols, identification of stable resistance sources, and validation of resistance across agroecological environments. Integrating fall armyworm resistance into high-yielding, agronomically adapted sorghum backgrounds could

strengthen crop resilience, reduce dependence on insecticides, and contribute to sustainable sorghum production and food security.

Keywords: Sorghum, fall armyworm, *Spodoptera frugiperda*, host plant resistance, crop improvement, antixenosis, antibiosis, insect tolerance, integrated pest management.

BIOLOGICAL INOCULANTS FOR RESILIENT AND SUSTAINABLE GREENHOUSE CHRYSANTHEMUM PRODUCTION: EFFECTS OF *Bacillus subtilis* AND *Pseudomonas fluorescens* ON GROWTH, DEFENCE RESPONSES AND FLOWER YIELD

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Abstract

Chrysanthemum (*Chrysanthemum morifolium* Ramat.) is an important commercial cut flower crop in which sustainable production requires approaches that support plant growth while reducing reliance on chemical inputs. Plant growth-promoting rhizobacteria, particularly *Bacillus subtilis* and *Pseudomonas fluorescens*, can improve crop performance and strengthen biologically based crop management. The present study evaluated these two biocontrol agents, applied through enriched farmyard manure (FYM) and foliar sprays, for their effects on growth, physiological defence responses, flowering and flower yield in standard-type 'Amalfi' and spray-type 'Punch' chrysanthemum. Fourteen treatments were compared, including an untreated control, farmers' practice, individual and combined bacterial inoculations at different concentrations, and *Corresponding foliar applications. Bacterial cultures were incorporated into FYM at 1 or 2 per cent, either individually or in combination, and foliar sprays were applied at 15, 30, 45 and 60 days after planting. Observations covered plant height, leaf number and leaf area at critical growth stages; total phenols, peroxidase, polyphenol oxidase and phenylalanine ammonia-lyase; rhizosphere populations of the introduced bacteria; flowering time, flower-stalk traits, quality-grade flowers and total yield per square metre. Treatment means were compared using Duncan's multiple range test at the 5 per cent significance level. The results indicated that bacterial treatments improved several growth, biochemical and floral traits relative to the untreated control, although responses differed between cultivars and treatments. Treatment T 12 , comprising soil + FYM (2:1) supplemented with 2 per cent *B. subtilis* and a 2 per cent *B. subtilis* foliar spray, produced the greatest plant height in 'Amalfi' at the flowering stage (148.67 cm) and the largest leaf area (1,350.25 cm²). Treatment T 13 , comprising soil + FYM (2:1) with 2 per cent *P. fluorescens* and a 2 per cent *P. fluorescens* foliar spray, recorded the highest flowering-stage plant height in 'Punch' (155.33 cm). T 12 also recorded high total phenol content and increased peroxidase activity, while T 13 showed the highest peroxidase activity in 'Punch' at flowering. These responses suggest enhanced activity

of biochemical pathways associated with plant defence. Yield results further highlighted the value of bacterial application. T 13 recorded the highest total flower yield in both ‘Amalfi’ (74.15) and ‘Punch’ (75.26), as reported in the experimental dataset, and the highest number of Grade A flowers in both types. The dataset does not specify the yield unit in the table heading beyond total yield per square metre; therefore, the values are presented as reported. Rhizosphere population data also showed increased bacterial counts in several inoculated treatments, supporting successful establishment of the introduced organisms. Overall, the findings indicate that targeted application of *B. subtilis* and *P. fluorescens* through FYM enrichment and foliar spraying can improve chrysanthemum growth, defence- related biochemical responses and marketable flower production. Among the tested treatments, T 13 was the most promising for total yield and Grade A flowers, while T 12 enhanced selected vegetative and biochemical traits. These results support further validation of microbial-based nutrient and crop-health management as a more sustainable component of chrysanthemum production. This integrated approach is relevant to resilience-oriented crop protection and warrants validation across seasons and production environments locally.

Keywords: Chrysanthemum; *Bacillus subtilis*; *Pseudomonas fluorescens*; biological management; plant defence responses; sustainable floriculture.

BHENDI YELLOW VEIN MOSAIC VIRUS: PATHOGEN BIOLOGY, DETECTION AND GENOME-EDITING STRATEGIES FOR SUSTAINABLE MANAGEMENT

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Abstract

Bhendi yellow vein mosaic disease (BYVMD), associated with Bhendi yellow vein mosaic virus (BYVMV), is one of the most destructive viral diseases affecting bhendi (*Abelmoschus esculentus* L. Moench), particularly in India and other tropical and subtropical regions. The disease causes characteristic yellowing of leaf veins and veinlets, chlorosis, reduced leaf size, stunted growth, and the production of small, poor-quality fruits, resulting in considerable yield and economic losses. BYVMV belongs to the genus Begomovirus and the family Geminiviridae and is primarily transmitted by the whitefly (*Bemisia tabaci*). Associated satellite DNA components can influence symptom development and disease severity. This review synthesizes current knowledge of the pathogen's taxonomy, genomic organization, transmission dynamics, epidemiology, and host–pathogen interactions. It also examines molecular detection methods, including polymerase chain reaction (PCR), rolling circle amplification (RCA), loop-mediated isothermal amplification (LAMP), and nucleic acid hybridization, which facilitate early detection and molecular characterization of viral infections. Current management relies on resistant or tolerant varieties, removal of infected plants, weed-host management, whitefly monitoring, and integrated pest management (IPM), although disease spread and vector-mediated transmission remain significant challenges. Emerging biotechnological approaches, particularly CRISPR/Cas9-mediated targeting of viral DNA and genome editing of host susceptibility genes, offer promising avenues for developing durable resistance. CRISPR/Cas13-mediated targeting of viral RNA transcripts represents an additional potential research strategy. However, the practical application of these technologies against BYVMV in bhendi requires further validation, including assessment of editing efficiency, resistance durability, crop performance, and biosafety. Integrating molecular diagnostics, conventional resistance breeding, effective vector management, and emerging genome-editing technologies may provide a more sustainable framework for disease management. Future research should prioritize the characterization of viral diversity,

identification of suitable host susceptibility factors, development of broad spectrum resistance, and field evaluation of promising genome-edited bhendi lines.

Keywords: *Abelmoschus esculentus*, *Bhendi yellow vein mosaic virus*, begomovirus, molecular detection, CRISPR/Cas9, genome editing, whitefly, integrated pest management.

EVALUATION OF SEAWEED EXTRACT FOR MITIGATING MOISTURE STRESS IN RICE (*Oryza sativa* L.)

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Abstract

A field experiment was conducted during the Navarai season (November, 2025 to March, 2026) at the College Farm, SRM College of Agricultural Sciences, SRM Institute of Science and Technology, Baburayanpettai, Chengalpattu, Tamil Nadu, to investigate the effect of Sea Weed Extract Application in Paddy (*Oryza sativa* L.) under Moisture Stress Conditions. The experiment was laid out in a Randomized Block Design (RBD) with eleven treatments and three replications. The treatments comprised T_1: 5% seaweed extract (SWE) spray + moisture stress at panicle initiation (PI) stage, T_2: 10% SWE spray + stress at PI stage, T_3: 15% SWE spray + stress at PI stage, T_4: 20% SWE spray + stress at PI stage, T_5: No SWE spray + stress at PI stage, T_6: 5% SWE spray + moisture stress at flowering stage, T_7: 10% SWE spray + stress at flowering stage, T_8: 15% SWE spray + stress at flowering stage, T_9: 20% SWE spray + stress at flowering stage, T_{10}: No SWE spray + stress at flowering stage and T_{11}: Control. Moisture stress was imposed by withholding irrigation for ten days at the respective stages, and the seaweed extract, prepared from a blend of *Kappaphycus alvarezii*, *Sargassum wightii* and *Ulva lactuca* (40:40:20), was applied as a foliar spray on the third day after stress imposition. Among the moisture-stressed treatments, foliar application of 20% seaweed extract at the flowering stage (T_9) recorded superior crop performance and was statistically on par with 15% seaweed extract at the flowering stage (T_8) for most growth, physiological and yield parameters. Treatment T_9 recorded higher plant height, tiller population, dry matter production, leaf area index, relative water content , SPAD chlorophyll value and membrane stability index, while T_8 exhibited statistically comparable performance for most of these traits. Application of seaweed extract significantly improved yield attributes and yield. The treatment T_9 produced the highest grain yield (5628 kg ha^{-1}) and straw yield (6887 kg ha^{-1}) among the moisture stressed treatments and was statistically comparable with T_8. Foliar application of 15% seaweed extract at the flowering stage (T_8) may be recommended as the optimum for improving sustainable rice production under moisture stress conditions.

Keywords: Growth, Rice, Seaweed, Moisture stress, Yield

GLOBAL SHIFT TOWARDS NANO-ENABLED CROP PROTECTION

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Abstract

Agriculture worldwide is moving towards lower chemical use. In India, nano fertilizers such as nano urea are already in field use, and research is expanding to nanopesticides for targeted control with lower chemical loads, nanosensors for real-time detection of pests and stress, and nanofertilizers for better nutrient delivery. Their benefits come from improved bioavailability, controlled release and activation of plant defence. In Europe, the EU Framework Directive on the sustainable use of plant protection products led to national plans such as the French Ecophyto plan, which made integrated pest management (IPM) and pest monitoring research priorities. Rising pesticide resistance and climate variability push other regions in the same direction. Nano silicon (nano silica) is one of the more promising materials. It helps plants withstand stress and disease, and porous forms can carry active ingredients for slow release. Innovation now begins at the seed. Nano-priming treats seeds with nanoparticles to improve germination, early vigour and stress tolerance, while nano seed packaging protects seed quality in storage by limiting moisture, pest and pathogen damage. Nano-based gene modification delivers DNA, RNA or CRISPR-Cas components into plant cells, offering potential routes to better pathogen resistance and reduced crop losses. Regulation and safety assessment still differ between countries, and environmental toxicity needs close attention. Despite these opportunities, environmental toxicity, effects on non-target organisms, production costs and regulatory uncertainties remain important challenges. Experience from programmes like Ectophyto suggests that farmers and other stakeholders must be involved from the start. This paper reviews seed-to-field nano-innovations that can support resilient and sustainable crop protection.

Keywords: Nano-priming, Nano seed packaging, Nanopesticides, Nano silicon, Nano -based gene modification, Sustainable crop protecti

BIOLOGICAL AND PLANT-DERIVED ALTERNATIVES TO SYNTHETIC FUNGICIDES FOR POST-HARVEST ANTHRACNOSE OF MANGO AND BANANA

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Abstract

Anthracnose caused by the *Colletotrichum gloeosporioides* species complex is a major source of post-harvest loss in mango and banana. Infection begins in the field, where the fungus sits quiescent in green fruit and produces sunken dark lesions only once ripening starts. A spray at harvest comes too late, so growers use post-harvest dips. Those dips rely on benzimidazoles or prochloraz, and residue limits in export markets, along with reduced sensitivity in some *Colletotrichum* populations, have made that harder to defend. This review compares antagonistic microbes (yeasts and *Bacillus* spp.) and plant essential oils as replacements, and looks at how each performs when paired with hot water treatment. The published results are uneven. Many studies report strong lesion suppression in vitro or on one cultivar under controlled conditions, but few test several cultivars, ripening stages or commercial storage temperatures, and essential oils at effective doses often change peel colour or flavour. Microbial antagonists work better when applied before infection than after it. Mild heat combined with an antagonist seems more consistent than either treatment alone, although this rests on a small number of trials. Dose reporting is not standardised, and cost per tonne is almost never given. We argue that the next studies should be run on naturally infected fruit through a full storage and ripening cycle, with the cost of treatment reported alongside efficacy.

Keywords: *Colletotrichum gloeosporioides*, post-harvest disease, biocontrol, essential oils, hot water treatment

EMERGING MOLECULAR TECHNOLOGIES FOR PLANT DISEASE DETECTION AND MANAGEMENT

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Abstract

Rapid and precise detection of plant pathogens is critical for preventing destructive disease outbreaks, safeguarding global crop production, and ensuring food security under changing climate conditions. Traditional diagnostic methods based on visual symptoms and culture-dependent isolation often fail to identify early-stage or asymptomatic infections. Recent advancements in molecular technologies have transformed plant pathology by enabling rapid, highly sensitive, and site-specific disease diagnosis and management. Polymerase chain reaction (PCR) variants, including quantitative real-time PCR (qPCR) and digital droplet PCR (ddPCR), provide robust quantification of low-abundance viral, bacterial, and fungal pathogens such as *Phytophthora infestans*, *Magnaporthe oryzae*, and *Xanthomonas oryzae* pv. *oryzae*. Isothermal amplification assays, notably Loop-Mediated Isothermal Amplification (LAMP) and Recombinase Polymerase Amplification (RPA), offer point-of-care, field-deployable diagnostics without requiring sophisticated laboratory thermal cyclers. Furthermore, Next-Generation Sequencing (NGS) and third-generation long-read platforms (e.g., Oxford Nanopore) allow unbiased high-throughput metagenomic surveillance, enabling early discovery of novel pathogens and monitoring of fungicide resistance genes. Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR)-based biosensing systems, particularly CRISPR-Cas12a and CRISPR-Cas13a, have emerged as ultra-specific, ultra-sensitive diagnostic tools capable of nucleic acid detection at attomolar concentrations. In disease management, RNA interference (RNAi) and host-induced gene silencing (HIGS) targeted against essential virulence genes in pathogens like *Fusarium oxysporum* and *Botrytis cinerea* provide non-transgenic, environmentally sustainable biopesticide alternatives. Integrating these emerging molecular diagnostics with nanotechnology-based smart delivery systems and digital decision-support frameworks promises field-scale, real-time monitoring and timely disease intervention, thereby strengthening climate-resilient crop health management.

Keywords: molecular technologies; plant disease detection; real-time PCR; LAMP; CRISPR-Cas biosensors; next-generation sequencing; RNA interference.

BIOLOGICAL CONTROL AND MICROBIAL SOLUTIONS FOR SUSTAINABLE AGRICULTURE

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Abstract

Biological control and microbial solutions represent a cornerstone of sustainable agriculture, offering eco-friendly alternatives to chemical pesticides and synthetic fertilizers. Continuous reliance on agrochemicals has led to soil degradation, biodiversity loss, and target pest resistance. Harnessing beneficial microorganisms—such as biocontrol agents, biofertilizers, and biostimulants—provides an integrated approach to enhance crop yield, suppress plant pathogens, and maintain soil ecological balance. Fungal biocontrol agents like *Trichoderma harzianum* and entomopathogenic fungi such as *Beauveria bassiana* and *Metarhizium anisopliae* play vital roles in suppressing soil-borne fungal pathogens and insect pests through hyperparasitism, antibiosis, and competition. Likewise, plant growth-promoting rhizobacteria (PGPR), including *Bacillus subtilis*, *Pseudomonas fluorescens*, and nitrogen-fixing *Rhizobium leguminosarum,* enhance plant nutrient availability, solubilize phosphorus, and induce systemic resistance (ISR) in host crops. Arbuscular mycorrhizal fungi (AMF), such as *Rhizophagus irregularis* (formerly *Glomus intraradices*), facilitate nutrient acquisition—particularly phosphate—and improve plant water relations during environmental stress. Microbial formulations also improve soil health, organic matter decomposition, and aggregate stability, thereby fostering climate-resilient farming systems. Integrating microbial inoculants into integrated pest management (IPM) and conservation agricultural practices reduces chemical runoff, protects beneficial soil biota, and supports long-term food security. This review highlights mechanisms of action, application strategies, current challenges in commercial bioformulations, and future prospects of microbial biotechnologies for sustainable agricultural production.

Keywords: biological control; microbial solutions, biopesticides, biofertilizers, plant growth-promoting rhizobacteria, disease management.

WATER-SAVING SUSTAINABLE PRACTICES FOR ENHANCING WATER USE EFFICIENCY IN AGRICULTURE: A REVIEW

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Abstract

Water scarcity is one of the major constraints for sustainable agriculture in semi-arid regions of Gujarat. Conventional flood irrigation leads to 40-50% water loss through evaporation and deep percolation. The present review focuses on water-saving sustainable practices that improve water use efficiency (WUE) while maintaining soil health and crop productivity. The study reviews four major practices: (i) Micro-irrigation (drip and sprinkler) which saves 30-60% water compared to flood irrigation, (ii) Mulching with crop residues and plastic mulch which reduces evaporation loss by 25-35%, (iii) System of Rice Intensification (SRI) and Alternate Wetting and Drying (AWD) in paddy which saves 20-30% water, and (iv) Conservation agriculture with broad bed furrow (BBF) and farm ponds for rainwater harvesting. Field trials conducted across Anand and Vadodara districts under Randomized Block Design (RBD) have shown that integration of drip irrigation with organic mulching increased WUE by 45% and improved soil moisture retention for 8-10 days longer than control. Adoption of these practices also reduced weed incidence and improved soil microbial activity due to reduced chemical input use. The review concludes that adoption of low-cost water-saving technologies like mulching, BBF, and protective irrigation through farm ponds are more feasible for small and marginal farmers in Gujarat than high-cost systems. Promotion of these practices through Kisan Melas and KVKs can ensure sustainable farming with 30-50% water saving.

Keywords: Water use efficiency, Sustainable farming, Micro-irrigation, Mulching, Conservation agriculture, RBD

EFFICACY OF FREEZE-DRIED *Streptomyces rochei* FORMULATION FOR THE MANAGEMENT OF FUSARIUM–NEMATODE DISEASE COMPLEX IN CUCUMBER AND CAPSICUM

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Abstract

The Fusarium–nematode disease complex is a major constraint to the production of vegetable crops, resulting in substantial losses in plant growth and fruit yield. The present study evaluated the efficacy of a freeze-dried cell formulation of *Streptomyces rochei* for managing the disease complex in cucumber and capsicum under greenhouse and polyhouse conditions. In the greenhouse evaluation on cucumber, soil drenching with a 2.5% formulation of *S. rochei* recorded the lowest disease incidence of 20.0%, *Corresponding to an 80.0% reduction over the untreated control. Subsequent polyhouse evaluations demonstrated the effectiveness of integrated application methods involving seed treatment, seedling dip and soil drenching. In cucumber, the combined application of all three treatments reduced disease complex incidence to 26.71%, representing a 69.2% reduction over the control. The treatment also reduced nematode infestation, with 111.7 nematodes per 250 g of soil, 21 galls per 5 g of root and a gall index of 3.0. The highest fruit yield of 23.65 t ha^{-1} was recorded with the combined application of the formulation. In capsicum, the integrated treatment reduced disease incidence to 23.3%, *Corresponding to a 73.1% reduction over the control, and restricted nematode infestation to 120.7 nematodes per 250 g of soil, with 20 galls per 5 g of root and a gall index of 3.0. The maximum fruit yield of 22.33 t ha^{-1} was also obtained with the combined treatment. Overall, the findings demonstrate the potential of freeze-dried *S. rochei* as a biological management option for the Fusarium–nematode disease complex in cucumber and capsicum. Integrated application through seed treatment, seedling dip and soil drenching provided the most favourable overall disease suppression and yield response, supporting further evaluation of this formulation for sustainable vegetable disease management.

Keywords: *Streptomyces rochei*, freeze-dried formulation, Fusarium–nematode disease complex, and biological disease management.

AI AND NANOTECHNOLOGY-BASED SMART DELIVERY SYSTEMS FOR PRECISION CROP DISEASE MANAGEMENT

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Abstract

Traditional crop protection practices often suffer from low efficiency, environmental leaching, and indiscriminate application of chemical pesticides, escalating environmental and ecological hazards. This paper explores the integration of Artificial Intelligence (AI) and nanotechnology to form smart delivery systems for precision crop disease management. Nanotechnology introduces novel carriers-such as nano-encapsulated formulations, polymeric nanoparticles, and mesoporous silica nanoparticles-capable of executing controlled, site- specific release of agrochemicals triggered by environmental cues like pH, temperature, or enzyme activity. Concurrently, AI systems, driven by machine learning algorithms and multi- spectral drone imagery, provide real-time diagnostic intelligence. By accurately identifying early-stage pathogenic symptoms and mapping disease hotspots, AI optimizes the deployment parameters for these nano-carriers. Merging localized, responsive Nano technological delivery with macro-level AI predictive modelling establishes a highly localized approach to plant protection. This synergistic paradigm significantly improves active ingredient usage efficiency, minimizes chemical toxicity in non-target ecosystems, and supports sustainable, high-yield agronomic practices.

Keywords: Smart Delivery Systems, Precision Agriculture, Nanotechnology, Agrochemicals, Artificial Intelligence, Crop Disease Management.

INTEGRATING AGRICULTURAL INNOVATIONS AND BIOLOGICAL TECHNOLOGIES FOR SUSTAINABLE CROP PROTECTION

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Abstract

Globally, agriculture is under rising pressure to reduce the ecological impact of intensive farming methods while ensuring food security. As estimated 20 to 40 percent of annual global crop production continues to be lost due to insects, pests, disease, and weed problems, and the chemicals that have traditionally controlled these problems are increasingly hard to safeguard. Insects, fungi, and weeds have developed more resistance that the regulations regarding active ingredients are getting stricter, and the environmental impact of pesticides is well known today. This assessment brings together the recent developments in major interdisciplinary areas, focusing on biological control agents, RNA interference (RNAi) approaches, advanced biopesticides, current plant breeding techniques, and delivery techniques. It should be noted that genomics and microbiome engineering have advanced native biocontrol agents and host resistance, while micro- and nanoscale encapsulation technologies have greatly helped the stability and delivery of biologically derived molecules. The assess digital and precision technologies that allow treatment techniques to be spatially and temporally specific rather than consistently used, such as remote sensing, disease detection using machine learning, and decision-making support. Integrated pest management models that utilize complementary techniques and integrate ecological understanding, as well as being adaptable to local farming conditions, produce the best results. Consequently, areas where research needs to focus include ways to deal with resistance to new modes of action, standard assessment of risks to biologicals and gene technologies, and using participatory approaches in which the farmers participate in technology generation. By dealing with these translational barriers and developing integrated management systems, sustainable crop protection can be brought from the sidelines to the mainstream of resilient agriculture

Keywords: Integrated pest management, bio-control agents, microbiome engineering, modern breeding, crop protection technology, Precision agriculture.

EFFECTIVENESS OF *Trichogramma japonicum* AGAINST OF PADDY STEM BORER

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Abstract

Front Line Demonstration (FLD) were conducted in 2022-23, 2023-24 and 2024- 25 to know the effectiveness of *Trichogramma japonicum* against paddy stem borer (*Scirpophaga incertulas walker*) as compared to farmer's practice of insecticidal treatments. The FLD was conducted on farmer's fields in Bhandara district in Maharashtra State. Results revealed that the infestation (%) of white ear heads due to paddy stem borer was found lowest in *Trichogramma japonicum* released fields with highest yields. The study found that cost of management of stem borer in *Trichogramma* released plots was less as compared to farmer's practice. Also found that increased CBR when compared with insecticidal management plot. *Trichogramma japonicum* found effective for management of paddy stem borer.

Keyword: Paddy stem borer, *Scirpophaga incertulas*, *Trichogramma japonicum.*

BIOLOGICAL CONTROL FOR SUSTAINABLE CROP PRODUCTION: ADVANCES, CHALLENGES, AND EMERGING OPPORTUNITIES

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Abstract

Biological control is increasingly being considered as a practical alternative to the excessive use of synthetic pesticides in crop production. It relies on naturally occurring organisms such as predators, parasitoids, fungi, bacteria, viruses, nematodes, and other beneficial microorganisms to reduce pest populations and suppress plant diseases. When properly used, these agents can lower pesticide inputs, reduce the risk of chemical residues, conserve beneficial organisms, and contribute to healthier agricultural ecosystems. Advances in microbial formulations, mass production, molecular techniques, micro biome research, and delivery systems have improved the prospects for developing more reliable biological control products. Biological control is particularly effective when combined with cultural, physical, botanical, and carefully selected chemical measures as part of integrated pest management. However, its performance under field conditions is not always consistent. Environmental factors, pest density, formulation quality, application timing, and interactions between biological agents and other organisms can strongly influence its effectiveness. Production costs, short shelf life, regulatory requirements, limited availability of quality products, and inadequate awareness among farmers also restrict wider adoption. Climate change may further affect these systems by altering pest distribution, population growth, and the activity of natural enemies. Recent developments in artificial intelligence, precision agriculture, genomics, nano-formulations, and microbial consortia offer new possibilities for improving the selection, formulation, and field application of biological control agents. For example, nano-formulated products, such as nano-encapsulated *Bacillus thuringiensis*, have demonstrated up to a 30–50% increase in field persistence and pest control efficacy compared to conventional formulations. This review examines recent advances in biological control, its major applications, existing limitations, and emerging opportunities for strengthening sustainable and climate-resilient crop production

Keywords: Sustainable agriculture, Crop protection, Climate change, precision agriculture, Microbial biocontrol.

PLANT EXTRACT-BASED NANO-HERBICIDE FOR SUSTAINABLE WEED MANAGEMENT IN GROUNDNUT (*Arachis hypogaea* L.)

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Abstract

Weeds are a major constraint in groundnut (*Arachis hypogaea* L.) production, causing significant competition for nutrients, water, sunlight and space, which adversely affects crop growth and productivity. The continuous reliance on synthetic herbicides raises concerns regarding environmental contamination, herbicide resistance and crop safety. Plant-derived herbicides offer an alternative approach because certain plants contain bioactive compounds with potential phytotoxic effects on weeds. Nanotechnology can be explored to improve the formulation, dispersion and stability of plant extracts through the development of nanoemulsions or other suitable nanocarrier systems. The present study aims to evaluate the potential of a plant extract- based nano-herbicide for sustainable weed management in groundnut. Selected plant extracts will be screened for their weed-suppressive activity, and promising extracts will be formulated using an appropriate delivery system. Different concentrations will be evaluated against an untreated control and a standard weed management treatment. Observations will include weed density, weed dry matter, weed control efficiency, crop phytotoxicity, crop growth and pod yield. The study is expected to provide information on the potential of plant-derived bioactive compounds for weed suppression and their suitability for integration into sustainable weed management practices. Further field validation and environmental safety assessment will be essential before recommending the technology for commercial use.

Keywords: Plant extract, nano-herbicide, groundnut, weed management, phytotoxicity, sustainable agriculture.

BIO CONTROL POTENTIAL OF BEEJAMRIT-DERIVED *Klebsiella aerogenes* 4KBPS2 AGAINST FUSARIUM WILT OF WATERMELON AND ITS PLANT GROWTH PROMOTING TRAITS

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Abstract

Fusarium wilt in watermelon, caused by *Fusarium oxysporum f. sp. niveum* (FON), is a predominant and destructive soil borne disease that causes significant yield loses up to 100% under severe conditions. At present, the control of Fusarium wilt depends on resistant cultivars and chemical fungicides. However, the continuous use of chemical fungicides causes environmental pollution and development of fungicide resistance. Therefore, the use of microorganisms as a biological control is an effective and environmentally safe approach for disease management. In this study, bacterial isolates obtained from Beejamrit bio formulation were evaluated for antagonist activity against FON using dual culture technique. Among the 50 bacterial isolates screened, a strain 4KBPS2 showed the highest inhibition rate of 73.20±2.1 against FON. Furthermore, volatile and non-volatile compounds produced by 4KBPS2 effectively suppress the FON mycelial growth under in vitro conditions. In pot experiments, strain 4KBPS2 showed a disease control efficiency of 40% compared to the control. Based on morphological characteristics, biochemical analysis and 16SRNA sequencing, strain 4KBPS2 was identified as *Klebsiella aerogenes*. Additionally, the strain *Klebsiella aerogenes* exhibited several plant growth-promotion activities, including synthesis of Indole acetic acid, siderophore, and phosphate solubilization. These findings suggest that *Klebsiella aerogenes* 4KBPS2 is a potential candidate for controlling FON and also promoting watermelon growth. However, further work including field evaluation, and biosafety assessment are necessary to validate its efficacy and suitability for agricultural application.

Keywords: Beejamrit, *Klebsiella aerogenes*, Fusarium wilt, watermelon.

METAGENOMIC AND PATHOGENIC INSIGHTS INTO *Oscheius chongmingensis* INDUCED HOST CADAVER MICROBIOME SHIFTS

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Abstract

Entomopathogenic nematodes (EPNs) are potent biological control agents widely used in integrated pest management due to their ability to parasitize and kill insect hosts within a short period through symbiotic associations with entomopathogenic bacteria. A metagenomic study was conducted on *Oscheius chongmingensis* infected *Galleria mellonella* cadavers and control cadavers to explore the associated bacterial microbiome. Metagenomic sequencing revealed distinct microbial community compositions between infected and control cadavers, highlighting the dominance of specific symbiotic and secondary bacterial populations in the infected cadavers. The study provides valuable insights into its taxonomy, pathogenic potential, and the microbiome associated with infected insect cadavers, contributing to a better understanding of the ecological role and biocontrol potential of *O. chongmingensis.*

Keywords: *Oscheius chongmingensis*, Entomopathogenic nematode, *Galleria mellonella*, Metagenomics, Biocontrol.

EFFICACY OF HOT WATER TREATMENT FOR DISINFESTATION OF FRUIT FLIES (*Bactrocera* sp.) IN MANGO (*Mangifera indica* L.)

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Abstract

Fruit flies and anthracnose are major constraints to mango production and export from South India, causing direct fruit damage, postharvest losses, and quarantine restrictions in international markets. Conventional hot water treatment (HWT) protocols require separate schedules, namely 48°C for 60 min for fruit fly disinfestation and 52°C for 5-10 min for anthracnose control. Moreover, the fruit fly treatment has been associated with severe internal breakdown (spongy tissue) in the cultivar Alphonso. This study aimed to develop and validate a single, short-duration HWT protocol capable of controlling both pests and diseases without compromising fruit quality. Mature green mangoes were immersed in hot water at 55°C for 20 min, followed by dipping in 5 % salt solution for 30 min. The treatment effectively controlled fruit fly infestation and anthracnose incidence while causing no internal breakdown, including in the spongy tissue-prone cultivar Alphonso. Compared with the existing quarantine treatment, the proposed protocol reduced treatment duration by approximately one-third. The findings demonstrate that this integrated HWT protocol is an effective, residue-free, and cost-effective alternative that replaces multiple post-harvest treatments while maintaining fruit quality and export suitability.

Keywords: Mango, hot water treatment, fruit fly, anthracnose, postharvest management, export quality.

INNOVATIVE AGRICULTURAL EXTENSION STRATEGIES FOR STRENGTHENING FARMWOMEN'S RESILIENCE TO EMERGING PESTS AND DISEASES

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Abstract

Emerging crop pests and diseases pose increasing challenges to sustainable agricultural production, while farmwomen often experience constraints in accessing timely advisories, diagnostic information and effective crop protection training. This study assessed farmwomen's awareness and preparedness regarding emerging crop pests and diseases, evaluated the perceived usefulness of different agricultural extension approaches, and proposed an integrated extension framework for strengthening resilience. The study was conducted among 120 farmwomen in Chengalpattu district, Tamil Nadu, using an ex-post facto research design, a structured interview schedule and focus group discussions. The findings revealed that 65.00 per cent of respondents were aware of emerging crop pests and diseases, while 60.00 per cent possessed knowledge of seasonal pest and disease protection practices. However, only 55.00 per cent reported the ability to identify early pest and disease symptoms, 45.00 per cent were aware of integrated pest management (IPM), and 40.00 per cent had access to timely pest and disease advisories. Field demonstrations were perceived as highly useful by 75.00 per cent of respondents, followed by Farmer Field Schools (70.00%), farmer-to-farmer knowledge sharing (67.50%) and mobile-based pest and disease advisories (60.00%). The findings indicate gaps between general awareness and practical preparedness, particularly in timely information access and IPM knowledge. An integrated, farmwoman-centric extension framework incorporating early detection, experiential learning, digital advisories, peer networks, sustainable pest management and feedback mechanisms is proposed. Strengthening linkages among farmwomen, self-help groups and Krishi Vigyan Kendras could improve access to knowledge and support timely crop protection decisions. Future studies should validate the proposed framework and assess its contribution to preparedness, adoption of IPM practices and resilience.

Keywords: Agricultural extension, farmwomen, emerging pests and diseases, extension strategies, integrated pest management, digital advisories, resilience.

INTEGRATION OF SENTINEL-2 SATELLITE IMAGERY AND FIELD ENTOMOLOGICAL OBSERVATIONS FOR PEST RISK PREDICTION

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Abstract

Crop pests are a major constraint to agricultural productivity, and the timely identification of pest-prone areas is essential for effective and sustainable crop protection. Conventional pest surveillance primarily relies on field scouting, which is labour-intensive and often limited in spatial coverage. Integrating field-based entomological observations with multispectral satellite imagery provides an opportunity to develop spatially explicit pest surveillance and risk prediction systems. The present study proposes an integrated framework using Sentinel-2 satellite imagery and field entomological observations to characterize spatial patterns of pest incidence and identify potential pest-risk zones. Sentinel-2 multispectral data were processed to derive vegetation indices, including the Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), and other spectral indicators representing crop vigour, canopy condition, and vegetation stress. Concurrently, field observations included pest species identification, pest abundance, crop growth stage, and geographic coordinates from representative sampling locations. We analysed spectral characteristics extracted from Sentinel-2 imagery against field-observed pest incidence to identify remotely detectable indicators associated with increased pest risk. The integrated field and satellite dataset provides a basis for developing spatial pest-risk models using statistical and machine-learning approaches. The resulting risk maps can support targeted field scouting and prioritize areas requiring intensive monitoring and timely intervention. Thus, the integration of Sentinel-2 remote sensing with field entomological observations offers a scalable approach for precision pest surveillance, early warning, and site-specific integrated pest management, with potential to improve the efficiency and sustainability of crop protection.

Keywords: Sentinel-2, remote sensing, field entomology, pest incidence, pest risk prediction, vegetation indices, precision pest management.

INTEGRATED RESILIENCE STRATEGIES FOR SUSTAINABLE CROP PRODUCTION AND CLIMATE-RESPONSIVE PLANT PROTECTION

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Abstract

Agricultural production systems are increasingly challenged by climate variability, emerging pests and diseases, soil degradation, declining biodiversity, and the growing need to reduce dependence on chemical inputs. Developing resilient agricultural systems requires the integration of sustainable crop production practices, ecological approaches, and innovative plant protection technologies. Climate-resilient crop varieties, integrated pest and disease management, biological control agents, precision agriculture, and improved soil health management play a vital role in enhancing crop productivity and stability under changing environmental conditions. Furthermore, the adoption of ecosystem-based approaches, early-warning systems, digital surveillance, and farmer-centric extension strategies can strengthen the timely detection and management of biotic and abiotic stresses. Integrating traditional knowledge with modern scientific innovations can further improve resource-use efficiency, biodiversity conservation, and long-term agricultural sustainability. A holistic approach that combines preventive, biological, cultural, and need-based chemical interventions is essential for maintaining crop health while minimizing environmental risks. This abstract highlights the significance of adaptive and integrated resilience strategies in promoting sustainable agriculture, safeguarding plant health, and ensuring food security under future climatic and ecological uncertainties.

Keywords: Climate resilience, Integrated pest management Crop health; Plant protection, Biological control

SUSTAINABLE CROP PROTECTION ON PEST

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Abstract

Sustainable crop protection is vital for productivity, environmental health, and food security. Innovations in biological and agricultural sciences offer eco-friendly alternatives to chemical pesticides. Beneficial microorganisms, parasitoids, predators, and entomopathogenic fungi help control pests and diseases. Plant biotechnology, genome editing, microbial biotechnology, and precision agriculture improve crop resistance and enable targeted management. Biofertilizers, biopesticides, plant extracts, and integrated pest management support soil health, biodiversity, and reduced chemical residues. Remote sensing, artificial intelligence, drones, and sensors enable early detection and precise control. Integrating biological methods with modern technologies can promote resilient, cost-effective, and sustainable crop protection.

Keywords: crop protection, biological control, biotechnology, remote sensing, artificial intelligence.

SUSTAINABLE MANAGEMENT OF DRY ROOT ROT OF BLACK GRAM: ROLE OF BIOLOGICAL CONTROL AND INTEGRATED DISEASE MANAGEMENT

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Abstract

Black gram (*Vigna mungo* L.) is an important pulse crop widely cultivated in India, but several soil-borne diseases constrain its productivity, with dry root rot caused by *Macrophomina phaseolina* as a major concern. The pathogen survives in soil and infected plant residues and can cause severe disease, particularly under environmental conditions favourable for disease development. Sustainable management of dry root rot requires approaches that reduce dependence on chemical fungicides while maintaining effective disease suppression. Biological control using beneficial rhizosphere microorganisms offers a promising and environmentally compatible alternative. Antagonistic bacteria can suppress soil-borne pathogens through mechanisms such as antibiosis, competition, production of hydrolytic enzymes, siderophore production and induction of plant defence responses. The integration of effective bacterial antagonists with seed treatment, soil application, organic amendments and other compatible disease management practices can improve disease suppression and plant growth. Advances in microbial characterization, molecular diagnostics, metabolite profiling and protein–ligand interaction studies can further support the identification of effective biocontrol mechanisms and bioactive compounds. This review highlights the importance of biological control and integrated disease management strategies for sustainable suppression of *M. phaseolina* and emphasizes the potential of rhizosphere antagonist bacteria as an important component of resilient crop protection systems in black gram.

Keywords: Black gram, dry root rot, biological control, rhizosphere bacteria, sustainable agriculture

BUILDING RESILIENT AGROECOSYSTEMS THROUGH SUSTAINABLE CROP HEALTH AND INTEGRATED PLANT PROTECTION

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Abstract

Agriculture faces increasing challenges from climate change, soil degradation, emerging insect pests and plant diseases, threatening crop productivity and global food security. Developing resilient agricultural systems through sustainable crop management and effective plant protection strategies is essential for maintaining crop health and environmental sustainability. This paper highlights integrated approaches for strengthening agricultural resilience, including climate-smart agriculture, crop diversification, conservation agriculture, soil health management and the use of climate-resilient crop varieties. Agroecological practices, beneficial microorganisms and plant growth-promoting rhizobacteria can improve soil fertility, nutrient uptake and crop tolerance to abiotic stresses. In plant protection, integrated pest management (IPM), biological control agents, botanical pesticides, pest-resistant cultivars and habitat management provide environmentally friendly alternatives to excessive dependence on synthetic pesticides. Furthermore, precision agriculture, remote sensing, artificial intelligence and early-warning systems can facilitate the timely detection of pest outbreaks and crop stress, enabling efficient and targeted management interventions. Recent research emphasizes the importance of combining ecological approaches with innovative technologies to improve resource-use efficiency, conserve biodiversity and reduce environmental risks. However, the successful implementation of these strategies requires locally adapted solutions, farmer participation, effective extension services and supportive agricultural policies. Assessing their effectiveness through crop productivity, soil health, pest suppression, economic viability and environmental sustainability is essential for long-term success. Integrating climate-resilient farming practices with sustainable plant protection can strengthen agricultural resilience, improve crop health and contribute to a more productive, environmentally responsible and sustainable agricultural future.

Keywords: Agricultural resilience, biological control, soil health, sustainable plantprotection.

CLIMATE-RESILIENT CROP HEALTH: INTEGRATING ENTOMOLOGICAL AND PLANT PATHOLOGICAL STRATEGIES FOR SUSTAINABLE AGRICULTURE

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Abstract

Agriculture is facing growing problems from insect pests, plant diseases, changing weather patterns and much reliance on chemical pesticides. These issues are putting pressure on crop yields harming the environment and risking food security. Finding ways to protect crops is important for keeping plants healthy and supporting sustainable farming. Climate change is shifting where pests live changing how insect populations grow affecting how pathogens survive and speeding up disease spread. Integrated pest and disease management (IPM and IDM) is an approach that blends cultural, biological, and mechanical and need-based chemical control methods. Integrated pest and disease management (IPM) uses crop varieties, crop rotation, intercropping balanced nutrient management and field sanitation to lower pest and disease pressure. Biological control agents, including parasitoids, predators and beneficial microorganisms such, as Trichoderma and Bacillus species give friendly options for reducing insect pests and plant pathogens. Emerging technologies like sensing, drones, artificial intelligence, automated pest surveillance and disease forecasting models can help detect problems early and support better decision-making.

Keywords: Climate resilience; Integrated pest management; Plant pathology; Biological control; Crop health; Sustainable agriculture.

RNA INTERFERENCE-BASED CROP PROTECTION: HARNESSING MOLECULAR BIOTECHNOLOGY FOR SUSTAINABLE PEST AND DISEASE MANAGEMENT

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Abstract

The number of insect pests and plant diseases is going up. At the time pesticides are not working as well as they used. People are also worried, about the environment. All of this has made it important to find better ways to protect crops. RNA interference or RNAi is a science method that can turn off specific genes in harmful creatures. This method gives farmers ways to control pests and diseases. It also helps reduce the use of pesticides. Combining RNAi with science and farming methods can help make farming better for the planet and keep crops healthier. RNA works by using RNA molecules that direct the breakdown or blocking of matching messenger RNA (mRNA) which lowers the activity of particular genes. In the control of insect pests, double-stranded RNA (dsRNA) can be created to attack genes that are needed for insect growth, eating, breeding or living. Likewise RNAi methods can aim at genes that are linked to infection, disease and growth of plant pathogens. Two key approaches are host-induced gene silencing (HIGS) where plants make RNA molecules that attack pests or pathogens and spray-induced gene silencing (SIGS) which means applying RNA molecules to plant surfaces from outside. These methods give flexibility to make crop protection tools. Future research should look into finding the molecular targets. It should also work on creating delivery systems that don't cost much. Scientists need to test how well these methods work in farm conditions. They should also check how these methods affect bugs and the environment. In the end, RNA interference is a step forward for agriculture and biology. It could help with precise ways to protect crops. It might also help deal with pests that have become resistant to pesticides. It could support pest and disease control that's kinder, to nature.

Keywords: RNA interference; Molecular biotechnology; Insect pest management; Plant pathology; Gene silencing; Sustainable crop protection.

INNOVATIVE APPROACHES IN BIOLOGICAL AND PRECISION-BASED CROP PROTECTION FOR SUSTAINABLE AGRICULTURE

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Abstract

Agricultural production faces growing threats from insect pests, plant diseases, and resistance to pesticides and changes in the climate. Traditional crop protection methods that use a lot of pesticides can harm helpful insects reduce wildlife diversity, damage soil health and lower overall environmental quality. Using control, new biotechnology and precise farming can give good chances to cut crop losses and keep the ecosystem balanced while ensuring food supplies stay safe. I have seen how these problems affect farms. Biological control is a part of keeping crops healthy in a sustainable way. It uses enemies, parasitoids, predators and helpful microorganisms to keep insect pests and plant diseases under control. Microbial agents like *Trichoderma spp., Bacillus spp*. And *Pseudomonas spp*.. Molecular tests and genomics are also part of this progress. Gene editing helps too combining all these ideas into programs like integrated pest management and integrated disease management helps use resources better. It reduces the need, for much pesticide. It helps make choices when managing crops . In conclusion mixing innovations with precision-based technology offers a hopeful route, to sustainable crop protection. These integrated approaches can improve crop health protect organisms cut environmental risks and help build resilient and productive agricultural systems.

Keywords: Sustainable crop protection; Biological control; Integrated pest management; Biopesticides; Precision agriculture; Plant pathology.

ECO-FRIENDLY INSECT PEST MANAGEMENT: INTEGRATING BIOLOGICAL CONTROL AND INNOVATIVE TECHNOLOGIES FOR SUSTAINABLE CROP PROTECTION

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Abstract

Insect pests are major constraints to agricultural production, causing considerable crop losses and threatening food security. The excessive use of chemical insecticides can result in pesticide resistance, environmental pollution, and harmful effects on beneficial insects. Therefore, sustainable and eco-friendly insect pest management strategies are essential for effective plant protection. Biological control, which involves the use of natural enemies such as predators, parasitoids, and entomopathogenic microorganisms, offers an environmentally friendly approach to suppressing insect pest populations. In addition, innovative technologies such as smart insect traps, digital pest monitoring, and artificial intelligence-based pest identification provide opportunities for early detection and timely pest management. Integrating these approaches with Integrated Pest Management (IPM), including cultural, mechanical, and need-based chemical control methods, can reduce dependence on synthetic insecticides and support resilient agricultural systems. This review discusses the importance of biological control, emerging pest monitoring technologies, and integrated approaches for sustainable insect pest management. It also highlights key challenges, including limited farmer awareness, implementation costs, and the need for effective field-level adoption. Combining ecological pest management practices with technological innovations can contribute to environmentally sustainable crop production, biodiversity conservation, and long-term food security.

Keywords: Insect pest management, Biological control, Integrated Pest Management, Sustainable agriculture, Plant protection.

INNOVATIONS IN AGRICULTURAL AND BIOLOGICAL SCIENCES FOR SUSTAINABLE CROP PROTECTION

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Abstract

Crop losses to pests, pathogens, and weeds remain a major constraint on global food security, while heavy reliance on synthetic pesticides has contributed to resistance development, biodiversity loss, environmental contamination, and risks to human health. Meeting rising food demand under climate change therefore requires crop protection strategies that are effective, economically viable, and environmentally sustainable. This paper reviews recent innovations at the interface of agricultural and biological sciences that are reshaping how crops are protected. We examine advances in integrated pest management (IPM), including improved monitoring, forecasting models, and threshold-based decision making. We then discuss biological control approaches, such as beneficial arthropods, entomopathogenic fungi, bacteria, and viruses, together with microbial biopesticides and plant growth-promoting microbiomes that enhance plant resilience. Molecular and genomic tools are covered, including marker-assisted selection, genome editing (CRISPR/Cas), and RNA interference (RNAi) for developing durable host-plant resistance and species-specific pest control. We also consider precision agriculture technologies, namely remote sensing, drones, sensors, and artificial intelligence-based disease and pest detection, which enable targeted, reduced-input interventions. In addition, we highlight plant-derived biochemicals, semiochemicals, and nanotechnology-enabled delivery systems as emerging alternatives to conventional chemistries.Finally, we discuss challenges to adoption, including regulatory pathways, scalability, cost, farmer awareness, and the need for resistance management and ecological risk assessment. We argue that integrating biological, genetic, and digital innovations within agroecological frameworks offers the most promising route to resilient, low-impact, and sustainable crop protection.

Keywords: sustainable agriculture; crop protection; integrated pest management; biological control; biopesticides; genome editing; RNAi; precision agriculture; plant microbiome

INNOVATIVE AND SUSTAINABLE APPROACHES FOR THE MANAGEMENT OF MAJOR RICE DISEASES: INTEGRATING BIOLOGICAL CONTROL, PLANT RESISTANCE AND PRECISION AGRICULTURE

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Abstract

Rice (*Oryza sativa* L.) is a major staple crop worldwide, but its productivity is increasingly threatened by diseases such as rice blast, bacterial leaf blight, sheath blight and brown spot. The excessive reliance on chemical pesticides for disease management raises concerns regarding environmental sustainability, pathogen resistance and the preservation of beneficial soil microorganisms. Therefore, innovative and environmentally friendly crop protection strategies are essential for sustainable rice production. This review examines recent advances in rice disease management, emphasizing biological control agents, plant growth-promoting microorganisms, resistant cultivars, biotechnological interventions and precision agriculture. Beneficial microorganisms, including Trichoderma, Bacillus and Pseudomonas species, offer potential for pathogen suppression through antagonistic activity, competition and activation of plant defence mechanisms. Advances in molecular breeding, genomic tools and gene-editing technologies provide additional opportunities to develop disease-resistant rice varieties. Furthermore, artificial intelligence, image-based disease diagnosis and digital crop monitoring may facilitate early disease detection and targeted management. Integrating these approaches with cultural practices and need-based pesticide application could reduce environmental impacts while improving crop health and productivity. Future research should prioritize field validation, cost-effective technologies and integrated management strategies suitable for diverse rice-growing environments. These innovations can contribute to resilient rice production, sustainable crop protection and long-term food security.

Keywords: Rice plant diseases; biological control; sustainable crop protection; integrated disease management; plant growth-promoting microorganisms; precision agriculture.

AI-DRIVEN PRECISION CROP PROTECTION FOR CLIMATE-SMART AGRICULTURE

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Abstract

Climate change has intensified the occurrence of crop pests and diseases, threatening agricultural productivity and sustainability. Artificial intelligence (AI)-driven precision crop protection offers an innovative approach through early pest and disease detection, predictive analytics, and site-specific management. Technologies such as machine learning, computer vision, remote sensing, drones, and Internet of Things (IoT) sensors enable real-time crop health monitoring and climate-based risk assessment. These tools facilitate targeted pesticide application, optimize input use, reduce environmental pollution, and minimize crop losses. Integrating AI with climate-smart agronomic practices can improve resource-use efficiency, strengthen crop resilience, and support sustainable crop production under variable climatic conditions. However, high implementation costs, limited digital infrastructure, and data accessibility remain major constraints, particularly for smallholder farmers. This review highlights the potential of AI-driven precision crop protection to enhance climate resilience, promote environmentally sustainable pest management, and advance climate-smart agriculture.

Keywords: Artificial intelligence, precision crop protection, climate-smart agriculture, pest management, machine learning, sustainable agriculture.

EVALUATING THE EFFICACY OF NATIVE PARASITOID WASPS FOR BIOLOGICAL CONTROL OF CROP PESTS IN CLIMATE-STRESSED AGROECOSYSTEMS

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Abstract

As climate change alters pest dynamics and accelerates their reproduction rates, chemical insecticides are becoming increasingly unreliable and environmentally unsustainable. Biological control using native natural enemies offers a resilient alternative; however, host-parasitoid interactions under climate stress remain poorly understood. This study investigates the parasitic efficiency and thermal tolerance of two native parasitoid wasp species (*Trichogramma spp*.) against the fall armyworm (*Spodoptera frugiperda*) across elevated temperature and fluctuating humidity conditions. Using controlled growth-chamber experiments combined with field trial validation, host searching behavior, parasitism rates, and emergence success were evaluated across three thermal regimes (25ºC, 30º, and 35º). Results demonstrate that while higher temperatures accelerate wasp development, extreme thermal spikes (>32ºC) significantly reduce adult longevity and egg-laying efficiency. However, microhabitat diversity within intercropped fields provided critical thermal refugia , mitigating performance drops. These findings highlight the potential of integrating thermal-tolerant native parasitoid strains into integrated pest management (IPM) strategies to sustain crop protection under changing global climates

Keywords: Biological control, native parasitoid wasps, (*Trichogramma spp*) fall armyworm, thermal tolerance, climate-stressed, thermal refugia.

EXPLORING INDIGENOUS BIOCONTROL AGENTS FOR SUSTAINABLE MANAGEMENT OF *Colletotrichum* IN CARDAMOM (*Elettaria cardamomum* Maton)

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Abstract

Cardamom (*Elettaria cardamomum* Maton), an economically important spice crop, is widely cultivated in the humid tropical regions of India. Its productivity and quality are influenced by several biotic and abiotic stresses, including fungal diseases. Species of Colletotrichum are important plant-associated fungi that can cause anthracnose and related diseases in various crops. However, the identity and role of Colletotrichum in any particular cardamom disease must be confirmed through appropriate pathogen identification and pathogenicity studies. The management of fungal diseases often relies on chemical fungicides, but their repeated and indiscriminate application may contribute to environmental contamination, disruption of beneficial microbial communities, and the development of fungicide resistance. Therefore, exploring indigenous biological control agents offers a promising approach to sustainable disease management and improved crop health. The present review explores the potential of indigenous microbial antagonists, particularly Trichoderma spp., Bacillus spp., and Pseudomonas spp., for the eco-friendly management of Colletotrichum-associated diseases in cardamom. Indigenous microorganisms isolated from cardamom rhizosphere soil, roots, and other plant-associated environments may possess useful antagonistic properties and could be better adapted to local agroecological conditions. Their potential mechanisms of action include competition for nutrients and space, production of antifungal metabolites and hydrolytic enzymes, mycoparasitism, and induction of host defence responses. Initial screening under laboratory conditions, using suitable dual-culture and other validated antagonism assays, can help identify promising microbial candidates. Selected isolates can subsequently be evaluated for their efficacy, compatibility, and stability under greenhouse and field conditions. Accurate identification of the pathogen, assessment of disease severity, and appropriate untreated and standard-treatment controls are essential for reliable evaluation. Integrating locally adapted biocontrol agents with cultural practices, disease-free planting material, field sanitation, and need-based fungicide application may help reduce dependence on chemical inputs while supporting sustainable cardamom production. Nevertheless, the effectiveness of indigenous

antagonists may vary with environmental conditions, formulation, application method, and interactions with the existing microbial community. Further validation under cardamom-growing conditions is therefore necessary before recommending specific strains for field use. Exploring indigenous biocontrol resources may contribute to the development of environmentally responsible plant protection strategies, strengthen crop resilience, and support the long-term sustainability of cardamom cultivation.

Keywords: Cardamom; Colletotrichum; indigenous biocontrol agents; Trichoderma; Bacillus; biological disease management; sustainable plant protection; rhizosphere microorganisms.

NATIVE PHYLLOPLANE BACTERIA AGAINST CERCOSPORA LEAF SPOT IN BHENDI (*Abelmoschus esculentus*)

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Abstract

Cercospora leaf spot, caused by *Pseudocercospora abelmoschi*, is a major fungal disease affecting bhendi (*Abelmoschus esculentus*), leading to significant yield losses. In this study, fifty native phylloplane bacterial isolates were obtained from healthy Bhendi leaves collected across various regions of Tamil Nadu, India. These isolates were characterized based on their morphological, cultural, and biochemical traits, and evaluated for their potential as biocontrol agents. Among these 50 phylloplane bacterial isolates, ten isolates (PB10, PB12, PB16, PB22, PB32, PB36, PB40, PB41, PB42, and PB43) exhibited significant antagonistic activity against P. abelmoschi under in vitro conditions. Out of these ten isolates, PB41 showed maximum growth inhibition of 53.33%, followed by PB32 (50.0%) and PB43 (47.78%). These effective isolates also exhibited plant growth-promoting traits, including phosphate and zinc solubilization, siderophore production, and catalase activity. Cluster analysis revealed that morphologically similar isolates formed distinct groups, some of which showed high potential for disease control and plant growth enhancement. The results indicated significant pathogen suppression, making these native phylloplane bacteria suitable as biocontrol agents for a sustainable and eco-friendly alternative to chemical fungicides for managing Cercospora leaf spot in bhendi.

Keywords: Leaf spot, Bhendi, inhibition, biochemical trails.

RESILIENCE STRATEGIES FOR SUSTAINABLE AGRICULTURE, CROP HEALTH AND PLANT PROTECTION

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Abstract

Agriculture is increasingly threatened by climate change, extreme weather events, soil degradation, emerging plant diseases, and insect pest infestations, which adversely affect crop productivity and food security. Developing resilient and sustainable agricultural systems is essential to ensure long-term agricultural sustainability and environmental protection. This review highlights various resilience strategies for sustainable agriculture, with particular emphasis on crop health and plant protection. Key approaches include climate-resilient crop varieties, crop diversification, conservation agriculture, integrated pest management (IPM), biological control, and the application of plant growth-promoting rhizobacteria (PGPR) and other beneficial microorganisms. Furthermore, induced plant resistance and eco-friendly biopesticides offer promising alternatives to excessive chemical pesticide use by enhancing plant defense mechanisms and reducing environmental risks. Sustainable soil and water management practices also contribute to improved crop growth and tolerance to abiotic stresses such as drought, salinity, and high temperatures. Integrating traditional agricultural knowledge with modern technologies can further strengthen farming systems against environmental and biological challenges. However, the adoption of these strategies may be limited by economic constraints, inadequate awareness, and insufficient access to appropriate technologies. Therefore, an integrated, ecosystem-based approach combining sustainable farming practices, biological crop protection, and climate adaptation is essential for maintaining crop health, reducing crop losses, conserving biodiversity, and ensuring long-term food security.

Keywords: Sustainable agriculture; Agricultural resilience; Crop health; Plant protection; Climate change adaptation; Integrated pest management (IPM).

RESILIENCE STRATEGIES FOR SUSTAINABLE AGRICULTURE, CROP HEALTH AND PLANT PROTECTION

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Abstract

Agriculture is increasingly challenged by climate change, emerging insect pests and diseases, declining soil fertility, and the excessive use of chemical pesticides. Developing resilient and sustainable agricultural systems is therefore essential for maintaining crop productivity, protecting biodiversity, and ensuring long-term food security. This abstract highlights the importance of integrated approaches that combine climate-smart agricultural practices, integrated pest management (IPM), biological control, crop diversification, resistant crop varieties, and improved soil health management. Cultural practices such as crop rotation, intercropping, field sanitation, and habitat management can help suppress pest populations and promote beneficial organisms. Biological control agents, including predators, parasitoids, and entomopathogenic microorganisms, offer environmentally compatible options for reducing pest damage and conserving natural enemies. Furthermore, regular pest monitoring, early-warning systems, and the judicious use of selective pesticides can improve pest management decisions and reduce unnecessary chemical applications. Research on push–pull technology in maize-based farming systems has demonstrated the potential of companion planting to reduce stemborer damage and improve crop yields. Integrating these strategies with farmer education, precision monitoring, and climate-resilient farming practices can strengthen agricultural resilience while supporting environmental sustainability. Therefore, a coordinated approach to crop health and plant protection is essential for developing productive, economically viable, and ecologically sustainable agricultural systems.

Keywords: Sustainable agriculture, agricultural resilience, crop health, plant protection, integrated pest management, biological control.

PLANT VOLATILE ORGANIC COMPOUNDS: ECOLOGICAL SIGNIFICANCE AND THEIR POTENTIAL APPLICATIONS IN SUSTAINABLE INSECT PEST MANAGEMENT

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Abstract

Plant volatile organic compounds (PVOCs) are low-molecular-weight, highly volatile, and predominantly lipophilic compounds released by plants that facilitate chemical communication within terrestrial ecosystems. These compounds, which include terpenoids, benzenoids, phenylpropanoids, fatty-acid derivatives, and microbially modified metabolites, play a crucial role in mediating interactions among plants, insects, and microorganisms. PVOCs perform diverse ecological functions, including attracting pollinators, influencing herbivore host selection and foraging behaviour, providing direct plant defence, recruiting natural enemies of herbivorous insects, and inducing defence responses in neighbouring plants through interplant signalling and priming. Increasing concerns regarding the adverse effects of conventional chemical pesticides on human health, environmental quality, and ecological balance have stimulated interest in plant-derived volatile compounds as potential tools for sustainable pest management. Depending on their chemical composition and concentration, these compounds can function as insect attractants, repellents, or behavioural modulators, offering opportunities for developing environmentally compatible pest management strategies. Current research focuses on understanding insect behavioural responses to PVOCs, their biosynthesis, modes of action, and detection by insect olfactory systems. Integrating analytical chemistry, chemical ecology, neurophysiology, bioinformatics, and molecular biology can provide deeper insights into the mechanisms underlying volatile-mediated insect behaviour. Further investigation into the identification, characterization, and field application of these compounds may support the development of effective, ecologically sound pest management strategies and strengthen integrated pest management (IPM) programmes.

Keywords: Plant volatile organic compounds (PVOCs); plant–insect interactions; insect olfaction; semiochemicals; plant defence; sustainable pest management

EXPLORING SEAWEED-DERIVED BIOACTIVE COMPOUNDS FOR INTEGRATED PEST AND DISEASE MANAGEMENT IN POLYHOUSE VEGETABLES

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Abstract

Polyhouse vegetable cultivation offers significant opportunities for enhancing productivity, improving produce quality, and ensuring year-round production. However, favourable microclimatic conditions and intensive cropping practices can increase the incidence of insect pests and diseases, necessitating effective and sustainable management strategies. Excessive dependence on synthetic pesticides raises concerns regarding pesticide residues, pest resistance, environmental contamination, and beneficial organism safety. Seaweed-derived bioactive compounds represent a promising eco-friendly approach for strengthening integrated pest and disease management in protected vegetable cultivation. Seaweeds contain diverse bioactive substances, including polysaccharides, alginates, laminarin, fucoidans, phenolic compounds, and oligosaccharides, which may promote plant growth, enhance stress tolerance, and activate plant defence mechanisms. Seaweed extracts can stimulate defence-related enzymes, improve nutrient uptake, and strengthen plant responses against selected pathogens and insect pests. Certain compounds also exhibit antimicrobial and antifeedant properties, although their effectiveness depends on seaweed species, extraction methods, formulation, crop type, and target organism. Integrating seaweed-based products with biological control agents, microbial biopesticides, botanical pesticides, resistant cultivars, and cultural practices can improve the sustainability of pest and disease management programmes. Furthermore, their potential compatibility with beneficial microorganisms offers opportunities for developing integrated and environmentally responsible crop protection strategies. The integration of seaweed-derived bioactive compounds into integrated pest and disease management programmes could reduce reliance on synthetic pesticides, support crop health, and promote sustainable vegetable production under protected cultivation.

Keywords: Seaweed extracts, bioactive compounds, polyhouse vegetables, integrated pest management, plant defence, biopesticides, sustainable crop protection.

SMART GREENHOUSE HYGIENE AND ROOT-ZONE MONITORING FOR SUSTAINABLE MANAGEMENT OF SOIL-BORNE DISEASES IN CUCUMBER

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Abstract

Protected cultivation of cucumber (*Cucumis sativus* L.) offers considerable potential for enhancing productivity, improving fruit quality, and ensuring year-round vegetable production. However, intensive cropping, inadequate greenhouse sanitation, and favourable environmental conditions can increase the incidence and spread of soil-borne diseases. Pathogens such as *Fusarium* spp., *Pythium* spp., and *Rhizoctonia solani* cause root rot, damping-off, and vascular wilting, leading to poor plant establishment and significant yield losses. Conventional disease management practices often depend on chemical fungicides, necessitating the development of sustainable, preventive, and technology-driven alternatives. Smart greenhouse hygiene combined with root-zone monitoring represents an effective approach to reducing disease risks and maintaining crop health. Essential hygiene practices, including the disinfection of tools, removal of infected plant residues, sanitation of growing substrates, management of irrigation water, and use of disease-free planting materials, help minimize pathogen introduction and transmission. Simultaneously, sensor-based monitoring of root-zone moisture, temperature, electrical conductivity, and pH facilitates precise irrigation and nutrient management while identifying conditions that may favour root diseases. Integrating these technologies with biological control agents, appropriate fertigation practices, and regular root inspection can strengthen integrated disease management strategies. Furthermore, digital monitoring systems and data-driven decision-making can support early identification of disease-conducive conditions and reduce unnecessary pesticide applications. The integration of greenhouse hygiene, precision root-zone monitoring, and biological disease suppression offers a promising strategy for sustainable cucumber production. This approach can improve resource-use efficiency, reduce disease-associated losses, and contribute to environmentally responsible, protected cultivation systems.

Keywords: Cucumber, Greenhouse hygiene, Root-zone monitoring, Soil-borne pathogens, Precision agriculture, Sustainable disease management.

SMART STICKY TRAPS TO TARGETED BIOCONTROL: A PRECISION IPM FRAMEWORK FOR WHITEFLY, THRIPS AND MITE MANAGEMENT IN POLYHOUSE CUCUMBER

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Abstract

Polyhouse cultivation of cucumber (*Cucumis sativus* L.) provides favourable conditions for enhanced productivity and year-round production; however, whiteflies, thrips, and mites remain major constraints to sustainable crop protection. These pests cause direct feeding damage, reduce plant vigour, affect fruit quality, and may facilitate the transmission of plant viruses. Excessive dependence on chemical pesticides can lead to pesticide resistance, disruption of beneficial arthropods, and environmental concerns. Integrating smart sticky traps with targeted biological control offers a promising precision integrated pest management (IPM) framework for protected cucumber cultivation. Colour-specific sticky traps, particularly yellow traps for whiteflies and blue or yellow traps for thrips, can support pest monitoring and help identify changes in pest populations. Digital imaging, automated insect counting, and sensor-assisted monitoring can further improve the timeliness and accuracy of pest surveillance. However, sticky traps alone are generally insufficient for reliable mite detection, which requires regular inspection of leaves using hand lenses or digital imaging tools. Pest monitoring data can guide the timely release of suitable biological control agents, including *Encarsia formosa* against whiteflies, predatory mites such as *Amblyseius swirskii* against thrips, and *Phytoseiulus persimilis* against spider mites. Combining these interventions with greenhouse sanitation, insect-proof netting, removal of infested plant material, and selective pesticide use can strengthen pest suppression while conserving beneficial organisms. The effectiveness of this framework depends on pest identification, crop conditions, biological control agent selection, and appropriate release timing. Integrating smart monitoring with targeted biocontrol can reduce unnecessary pesticide applications, improve pest management efficiency, and promote sustainable cucumber production under protected cultivation.

Keywords: Cucumber, Smart sticky traps, Whiteflies, Thrips, Spider mites, Biological control, Precision integrated pest management.

DEEP LEARNING-BASED DETECTION OF GREATER WAX MOTH (*Galleria mellonella*) INFESTATION IN INDIAN HONEY BEE (*Apis cerana indica*) COLONIES USING DIGITAL IMAGES

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Abstract

The greater wax moth (*Galleria mellonella*) is a major pest of honey bee colonies, causing damage to combs, brood, and stored hive materials. The present study aims to develop a deep learning-based approach for detecting wax moth infestation in Indian honey bee (Apis cerana indica) colonies using digital images at SRM College of Agricultural Sciences, SRM Institute of Science and Technology, Baburayanpettai, Chengalpattu, Tamil Nadu, India. Digital images of healthy and wax moth-infested combs will be collected and classified using a convolutional neural network (CNN). The image dataset will be divided into training, validation, and testing sets for model development and evaluation. Classification performance will be assessed using accuracy, precision, recall, F1-score, and Receiver Operating Characteristic–Area Under the Curve (ROC-AUC). The proposed approach is expected to facilitate rapid, non-invasive, and reliable identification of wax moth infestation, supporting timely pest management and improved colony health. This study will provide a foundation for developing an image-based decision-support tool for sustainable management of Indian honey bee colonies.

Keywords: *Apis cerana indica, Galleria mellonella*, deep learning, digital images, convolutional neural network, wax moth infestation.

NATIVE PHYLLOPLANE BACTERIA AS POTENTIAL BIOCONTROL AGENTS AGAINST MANGO ANTHRACNOSE CAUSED BY *Colletotrichum gloeosporioides*

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Abstract

Mango is an economically important tropical fruit crop and anthracnose caused by *Colletotrichum gloeosporioides* is one of its most destructive diseases, resulting in significant pre and post-harvest losses. The present study aimed to isolate and characterize *C. gloeosporioides* and evaluate the antagonistic potential of native phylloplane bacteria against the pathogen under *in vitro* conditions. The pathogen was isolated from infected mango fruits and identified based on morphological and molecular characteristics. Genomic DNA was extracted using the CTAB method and the internal transcribed spacer (ITS) region was amplified using ITS1 and ITS4 primers. Sequence analysis confirmed the identity of the pathogen as *C. gloeosporioides* and the ITS sequence was deposited in the NCBI GenBank database under accession number KT282667. A total of 32 native phylloplane bacterial isolates were recovered from healthy mango leaves and fruits using leaf washing and direct plating techniques. Preliminary screening by the quadrant streak method identified ten promising antagonistic isolates, which were further evaluated employing the dual culture method. Of these, isolate PB15 showed the greatest mycelial growth inhibition (71.3%), followed by PB7 (68.4%) and PB22 (66.0%). The results demonstrate that native phylloplane bacteria possess significant antagonistic activity against *C. gloeosporioides* and could serve as potential biocontrol agents for the sustainable management of mango anthracnose

Keywords: Anthracnose, *Colletotrichum gloeosporioides*, Phylloplane bacteria, Antagonist, Molecular characterization, Inhibition

BIOCONTROL POTENTIAL OF *Bacillus velezensis* STRAIN MB2 IN THE MANAGEMENT OF *Pyricularia grisea* INFECTING FINGER MILLET *Eleusine coracana* L. Gaertn

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Abstract

Pyricularia grisea inciting ragi blast is one of the important diseases infecting finger millet *Eleusine coracana* L. Gaertn. The incidence surveyed in different districts of Tamil Nadu revealed the disease severity of 44-48%. The disease index was analyzed using the grade chart IRRI (1996). The disease symptoms were observed in all the stages starting from seedling to harvesting stage. The disease was found to be devastating in the seedling stage. Pathogen was isolated, its pathogenicity was confirmed. Morphology and molecular confirmation were performed (PX945787) for the virulent isolate. Tricyclazole is widely used for the management of blast pathogen. Though it has low toxicity, the residue can affect the environment. Twenty endophytic bacterial population was isolated from different *Poacea* group of plants and tested for their bio efficacy. Among all the isolates tested *in vitro*, *Bacillus velezensis* (PZ628156) was observed to be most effective recording the lowest mycelial growth of 5.33 mm and the highest percentage inhibition of 93.20% (68.76), followed by *Pseudomonas fluorescens* (PZ645246) exhibiting inhibition percentage of 92.36% (67.51). the same isolates were taken for evaluation under pot culture experiment. Different treatments were compared with a standard check (Tricyclazole 0.1%). Three consecutive spraying was given at fortnight intervals. Tricyclazole (0.1%) remained the most effective treatment after each spray, recording the lowest PDI of 19.86% (26.46) with 57.13% disease reduction, followed by *Bacillus velezensis* (T3), 24.76% (29.83) with 46.55% disease reduction as when compared with uninoculated healthy control where it remained completely disease free. Whereas, *Pseudomonas fluorescens* which was effective under *in vitro* was not found to performed better under pot culture conditions. The maximum plant height was also recorded in plants treated with bacterial consortium (*Bacillus velezensis* + *Pseudomonas fluorescens*) (68.11 cm) as when compared with healthy control which recorded the minimum plant height of 45.11 cm. Thus, the experiment reveals that,

Bacillus velezensis isolated from *Poacea* group of plant can be effectively exploited as a biocontrol agent for the management of blast pathogen *Pyricularia grisea* infecting finger millet. The same can also be exploited for the management of *Pyricularia* spp infecting crops such as rice, wheat, pearl millet, etc.

Keywords: *Pyricularia grisea*, *Bacillus velezensis*, Biocontrol agent, Quality improvement, Finger millet

DIAGNOSIS OF BANANA BUNCHY TOP VIRUS IN RED BANANA

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Abstract

Banana Bunchy Top Disease (BBTD) caused by the Banana Bunchy Top Virus (BBTV), is the most serious virus disease of banana and plantain worldwide. Detection of the BBTV infection in the planting material could help in the effective management of the disease in banana. A polymerase chain reaction (PCR) assay was used to detect the of banana bunchy top virus at early stages of infection in banana suckers before the expression of symptoms. In the present study, primers were designed for amplification of the BBTV coat protein (CP) gene and the gene of 513 bp size was successfully amplified through polymerase chain reaction (PCR). The amplified PCR product was cloned and sequenced. The homology search of the sequence using NCBI blast showed similarity (99%) to ten CP gene sequences and are 98% similar to four CP gene sequences. 40 randomly selected banana suckers were subjected for the detection of BBTV through PCR. Out of 40, size specific amplification of coat protein gene was found, which indicates infection of planting material with BBTV. The PCR result was confirmed and validated through Dot blot hybridization analysis by using sequences of BBTV CP gene as probe.

Keywords: red banana, BBTV viral Coat protein gene, PCR, Dot blot hybridization, cloning

PRECISION TECHNOLOGIES FOR RESILIENT FRUIT PRODUCTION

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Abstract

The increasing incidence of emerging pests and pathogens, climate driven disease outbreaks and the evolution of pesticide resistance necessitate a paradigm shift from conventional plant protection towards biologically informed and technology driven resilience strategies in fruit crops. Recent advances in plant immunity, rhizosphere and phyllosphere microbiome research, molecular diagnostics and precision horticulture provide new opportunities to enhance crop resilience while reducing dependence on synthetic pesticides. This review explores the integration of host resistance mechanisms, induced systemic resistance (ISR), systemic acquired resistance (SAR), beneficial microbial consortia and microbiome engineering as complementary approaches for strengthening plant defence against major insect pests and pathogens. Particular emphasis is placed on the roles of plant defence signalling pathways, including salicylic acid, jasmonic acid and ethylene in mediating resistance responses and regulating interactions between fruit crops, pathogens and beneficial microorganisms. Emerging technologies such as remote sensing, artificial intelligence, machine learning, geographic information systems and weather based disease forecasting are examined for their potential to enable early detection, risk prediction and site-specific plant protection. In addition, precision delivery of biocontrol agents, RNA based pest management and genome assisted breeding are discussed as promising approaches, subject to crop specific validation, regulatory approval and practical feasibility. The potential integration of these innovations in mango, citrus, guava, banana, pomegranate and other commercially important fruit crops is considered, with attention to perennial orchard systems and their complex ecological interactions. Major challenges include variability in microbial efficacy under field conditions, limited long-term datasets, infrastructure costs, regulatory constraints and the need for multidisciplinary research. A system based framework combining plant immunity, microbiome functionality, ecological management and digital decision support could facilitate the transition towards predictive,

precise and resilient fruit crop protection. Future research should prioritize field validation, multilocation trials, economic assessment and scalable technologies to support sustainable fruit production under changing climatic conditions.

Keywords: Precision plant protection, microbiome engineering, RNA based pest management, fruit crops

LEAF–TWISTING WEEVIL, *Apoderus tranquebaricus* Fab. (CURCULIONIDAE: COLEOPTERA) ON WATER APPLE TREE, *Syzygium aqueum* (Burm. f.) Alston (MYRTACEAE): A NEW RECORD OF HOST PLANT IN TAMIL NADU, INDIA

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Abstract

Water apple, botanically known as *Syzygium aqueum* comes under the family myrtaceae and common name of this fruit is Panneer Naval, Water apple, Watery rose apple, Water Cherry, Java apple, Bell apple and Bell fruit. This is a tropical fruit and native to South East Asia. This is evergreen tree with a dense, spreading crown and growing up to 12 meters in height. The tree requires heavy rainfall and survives in moist tropical lowlands at altitudes of 1200 - 1600m from sea level. Branches grow at 1 m height in short trunk. Leaves are oblong to elliptic with very short petioles. It's a small bell shaped fruit with red, pink or green colour thin skin, spongy and fragrant with an aromatic flavor which is edible for human consumption. Fruits are watery and mature during May – June. It can able to flower and fruit two or three times in a year. Though water apple is a under exploited fruit Leaf eating caterpillars (Slug caterpillar, Hairy caterpillar, Leaf webber, Leaf Miner and semilooper), fruit flies, scales, whiteflies and mealy bug are the common pests reported in Water apple so far. The leaf twisting weevil, *Apoderus tranquebaricus* Fab. (Curculionidae: Coleoptera) mainly affects tree crops like Mango, Jamun, Jackfruit, Teak, Cashew, Neem, Sapota, Guava, Almond (Selvam, 2023) and Indian butter tree (Manikandan and Rengalakshmi, 2023). Water apple, *Syzygium aqueum* were recorded with the *Apoderus tranquebaricus* Fab. weevil which is an interesting examples of complex, genetically determines behaviors.Studies on seasonal incidence of leaf feeding insects commonly attacking long red variety water apple (300 trees) which was planted in the year 2022 were taken up in the orchard of Sethu Bhaskara Agricultural College and Research Foundation (Latitude 9.8236° N and Longitude 78.8340° E), Karaikudi, Sivagangai district, Tamil Nadu. During the course of study of leaf damaging insects in water apple, for the first time leaf infestation by the leaf twisting weevils was noticed from the month of December 2025 to March 2026 on the foliage's of water apple, *Syzygium aqueum.* The leaf twist of weevil is referred to as a nidus. After mating the females construct typical brood rolls from the leaves of their host plant. It has the habit of cutting and twisting the fresh leaves into shapely thimble

like rolls from tip of the leaf to mid of the leaf which remain attached to the leaf in tree itself. The leaf cutting pattern often varies from species to species. The leaf cutting types are as follows cutting type, curved cutting type, non – cutting type, L-shaped cutting type, straight – cutting type and quasi – cutting type (Park *et al.,* 2007). Eggs are laid singly in the peripheral region by the adult weevil in each leaf roll. The grubs feed on the leaf tissue within the leaf roll. During the early stage, the grubs were small, sluggish in movement and were pale yellow in colour without legs. In the matured stage, the grubs were yellowish colour, "C" shaped with black small sting like structure and actively feeding on the twisted region of the leaf. Pupation takes place within the leaf roll. For identification and confirmation, the weevils were collected with the help of long handled insect net and killed in the insect killing bottle by using ethyl acetate and the killed specimens were then pinned properly and kept in insect boxes containing naphthalene balls for subsequent identification. Later after through morphological studies the weevils were identified as *Apoderus tranquebaricus* Fab. With the help of the past available literatures Manjunath and Umamaheshwari (2018) and also by comparing the already identified specimen kept in Entomology Laboratory, SBAC & RF, Karaikudi. The adult weevils are medium – sized, characterized by a reddish – brown coloration and possess a long snout. Adult with the long snout rostrum scrapping the chlorophyll content from the leaf surface, holes with lined structure shows dark reddish brown dried as an injury symptom. Infestation starts from the month September (2025) where the visual symptoms were appeared in December (2025) and peak infestation occurred in the month of January (2026), this might be due availability of new shoots during the period. Likewise, Manjunath and Umamaheshwari (2018) recorded the peak incidence during September in Mango. It can be concluded that *Apoderus tranquebaricus* Fab. is the leaf twisting weevil of water apple and these weevils form leaf roll in water apple leaves. As the existence of this insect pest on *Syzygium aqueum* has not been recorded earlier, so that it is being reported for the first time from Tamil Nadu and this new host plant record for the weevil, *Apoderus tranquebaricus* Fab. creates a noteworthy impact for further studies on water apple and insect pest interaction.

Keywords: Water apple, Leaf roll, *Apoderus tranquebaricus,* Seasonal incidence

EFFECT OF ZnO NPs AND BIOFORMULATIONS IN IMPROVING THE PEST RESISTANCE OF LETTUCE IN A HYDROPONICS SYSTEM

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Abstract

The present investigation was carried out under controlled hydroponic conditions at the Experimental farm (Jaya farm), Galipooje, Doddaballapura Taluk, Bengaluru, Karnataka, during January-April 2026. The unit is situated at 13°31' N latitude and 77°49' E longitude at an elevation of 910 m above Mean Sea Level (MSL). The Romaine lettuce *variety Lactuca sativa* L. var. *longifolia* was used for the experiment. The experiment was laid out under a completely Randomized Design (CRD) with nine treatments and three replications, including an untreated control, to evaluate the influence of zinc oxide nanoparticles (ZnO NPs) at two concentrations (50 and 100 ppm), individually and in combination with bioagents *Bacillus siamensis* and *Beauveria bassiana*, and the botanical agent Azadirachtin 1%, on the growth, yield and quality characteristics of lettuce. Results demonstrated that the thrips population was effectively suppressed by the treatments containing Azadirachtin and *Beauveria bassiana*. Among the treatments, foliar application of Azadirachtin at 1% + *Beauveria bassiana*) recorded the lowest thrips population at 30 DAT (2.3 plant^{-1}) and harvest (1.1 plant^{-1}), compared with 8.6 and 12.8 plant^{-1} in the untreated control. Aphid population showed an even stronger response to the combined treatments. T_6 (ZnO NPs at 50 ppm + Azadirachtin at 1% + *Beauveria bassiana*) recorded the lowest aphid population at 15 and 30 DAT, while T_8 (ZnO NPs at 100 ppm + Azadirachtin at 1% + *Beauveria bassiana*) was most effective at harvest, with only 1.0 aphid plant^{-1} compared with 11.5 plant^{-1} in the untreated control, *Corresponding to a reduction of about 91 per cent. Treatment means were tested for significant differences using the standard error of difference (SEd) and critical difference (CD) at $P \leq 0.05$.

Keywords: Azadirachtin, *Bacillus siamensis, Beauveria bassiana*, Hydroponics, Lettuce, Zinc oxide nanoparticles (ZnO NPs).

SMARTPHONE UTILIZATION BEHAVIOUR OF RICE FARMERS FOR ACCESSING INFORMATION RELATED TO PEST AND DISEASE MANAGEMENT

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Abstract

Smartphones have emerged as an important digital tool for disseminating timely agricultural information to rice farmers. Effective pest and disease management requires access to reliable, location-specific, and timely information to support informed decision-making. However, the extent to which rice farmers utilize smartphones to access and apply such information may vary considerably. Understanding their smartphone utilization behaviour is essential for developing targeted digital extension strategies and improving pest and disease management practices. With this view the research was conducted to study the Smartphone Utilization Behaviour of Rice farmers for accessing information related to pest and disease management. The study was conducted in the Thanjavur district, since the district possess major share of rice cultivation area in Tamil Nadu. A total of 60 respondents were randomly selected for the research from three villages in the count of 20 respondents form one village. From the study it was found that most of the farmers (89.00%) were unaware of the mobile applications related to pest and disease management and cent (100.00%) per cent of the respondents were not using smartphones to access the information related to pest and disease identification and to search the control measures due to the constraints of lack of education (Rank I), high experience (Rank II) and fear of failure (Rank III). The study suggests strengthening digital agricultural extension through practical smartphone training, promotion of reliable agricultural mobile applications, and continuous technical support from extension personnel. Integrating farmers' experiential knowledge with scientific digital information and providing confidence-building demonstrations could facilitate effective smartphone utilization for pest and disease management among rice farmers.

Keywords: Smartphone, information, utilization behaviour and pest and disease management

RESILIENCE STRATEGIES FOR SEED PROTECTION FROM INSECTS

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Abstract

Insect infestation during seed storage reduces physical purity, seed weight, germination, seedling vigour and the economic value of planting material. Resilient protection must therefore achieve two outcomes simultaneously: restrict pest survival and reproduction while maintaining seed physiological quality until sowing. This chapter reviews preventive handling, moisture and temperature management, hermetic packaging, botanical protectants, inert dusts, entomopathogens, improved coatings and early-warning systems. Recent field and laboratory evidence indicates that hermetic storage can suppress insect damage and maintain germination, while selected botanical or microbial treatments may provide additional protection under defined conditions. However, insect efficacy does not necessarily indicate embryo safety and results from food grain cannot be uncritically transferred to planting seed. An integrated seed-protection programme should combine clean seed lots, suitable packaging, pest surveillance, crop-specific treatment validation and periodic germination testing.

Keywords: stored-seed insects; seed viability; hermetic storage; botanical protectants; integrated pest management; seed vigour

1. Introduction

Seeds are living propagules, unlike grain stored only for consumption. Damage that removes a small amount of seed tissue can have large consequences when feeding affects the embryo or essential reserves. Insects may also introduce contaminants, promote heating and create opportunities for fungal invasion. Seed-storage resilience is the capacity of a handling and storage system to prevent infestation, maintain germination and recover quickly when pests are detected. It is especially relevant to smallholder seed systems exposed to warm temperatures, seasonal humidity, repeated bag handling and limited access to controlled stores. Recent field experiments on paddy and maize found that hermetic packaging reduced insect pressure and better maintained seed germination than porous conventional bags (Khandai et al., 2025; Khalid et al., 2026). These responses depend on initial moisture, package integrity, crop,

storage duration and starting seed quality. The central consideration is not simply the number of dead insects, but whether a seed lot remains fit for sowing.

2. Important insect pests and types of damage

Primary pests can attack intact seeds. Examples include the rice and maize weevils (*Sitophilus oryzae* and *S. zeamais*), lesser grain borer (*Rhyzopertha dominica*), Angoumois grain moth (*Sitotroga cerealella*), and pulse beetles (*Callosobruchus spp.*). Secondary pests, including many flour beetles (*Tribolium spp.*), frequently exploit broken or previously damaged material. Internal feeders are particularly difficult to detect because larvae develop within grains or seeds before adults emerge. In legumes, bruchid feeding can destroy cotyledon reserves and injure the embryonic axis; in cereals, boring and repeated feeding contribute to loss of dry matter and germination. Species identification matters because pest biology and susceptibility differ, and the treatment appropriate for a seed lot must be distinguished from that used for food grain.

3. Prevention begins before storage

Resilient protection starts with timely harvesting, careful threshing and rapid removal of field-infested or damaged seed. Clean, grade, and dry seed lots to a moisture content appropriate for the crop and storage duration before packaging. Record initial germination, moisture content, physical purity, and visible insect infestation. Cleaning removes broken kernels and extraneous material that harbour secondary feeders; it does not reliably eliminate insects concealed within intact seed. Inspect and clean storage buildings and empty containers before new lots arrive. Remove old residues, spilt grain, and infested bags, and keep new seed separate from older material. Pallets, good drainage, leak protection, and pest-resistant access points reduce the risk of reinfestation. Seed should remain correctly labelled and traceable by crop, cultivar, lot, harvest date and treatment history. When sealed bags are used, frequent opening defeats their protective purpose; monitoring may instead rely on inspecting representative bags and store-level surveillance.

4. Moisture, temperature and the storage environment

Seed moisture and temperature influence both insect development and seed ageing. In ordinary orthodox seeds, sufficiently low moisture and cool storage generally slow deterioration, but no single moisture target is appropriate because safe levels depend on species, oil content, packaging, and expected storage time. Even excessively wet seeds sealed in an airtight system can deteriorate or support fungal growth; hermetic packaging does not dry the seed. Recalcitrant seeds, which are sensitive to desiccation, require a different approach from dry-

storable cereal or pulse seeds. Low-temperature storage and controlled atmospheres may be valuable for high-value or long-duration seed reserves, provided species-specific tolerance and cost are considered. Sudden temperature changes can produce condensation when cold containers are opened in humid air. Therefore, germination tests should accompany temperature and moisture records. Germination testing should follow applicable standard seed-testing procedures and local certification requirements.

5. Hermetic storage as a core resilience strategy

Hermetic bags and properly sealed drums restrict gas and moisture exchange. Insects and other organisms respire, gradually reducing available oxygen and increasing carbon dioxide, which inhibits insect activity and reproduction. Reduced oxygen availability is one mechanism of insect suppression in airtight storage, but its effectiveness depends on the sealing conditions and insect population. These systems provide an important low-residue option, but performance depends on intact seals, low initial seed moisture, and avoiding sharp objects or rodents that puncture liners. Recent seed-focused studies show the practical benefit. In Assam, Khandai et al. (2025) found that hermetic super grain bags reduced infestation and improved germination of stored paddy compared with gunny bags. In a separate paddy storage study, Sivashankari and Khandai (2025) recorded 91.7% germination in hermetic bags compared with 68.2% in conventional bags under their test conditions. In humid locations of Pakistan, Khalid et al. (2026) reported that hermetic bags and drums better maintained maize seed quality over eight months, whereas conventional polypropylene bags showed moisture uptake and greater insect pressure. These are context-specific results, not guaranteed germination percentages across crops. For seed producers, hermetic systems are particularly useful as preventive packaging after drying and lot inspection. Check their suitability against storage duration, seed quantity, handling frequency, damage risk, and the need to access samples for quality testing.

6. Botanical seed protectants

Botanical powders, extracts and essential oils may act as repellents, feeding deterrents, oviposition inhibitors or contact and fumigant toxicants. Neem-derived materials, *Acorus* formulations and locally available aromatic plants have attracted interest because they can be produced from renewable resources. Nevertheless, botanical materials are not automatically non-toxic to seeds or operators: their composition varies with plant source, extraction method, concentration and storage conditions. The same volatile compounds that affect insects may also impair germination or seedling growth at inappropriate doses. Botanical efficacy is crop-

specific: Kooner et al. (2023) reported reduced bruchid damage with neem-based treatments, although they also considered biochemical grain responses. In stored mung bean, Spandana et al. (2025) reported that selected azadirachtin and *Acorus* treatments suppressed *Callosobruchus maculatus* and retained germination at approximately 85-87% over a five-month laboratory study, compared with substantially lower germination in the untreated control. In sorghum, Radhakrishnan et al. (2025) found an *Acorus calamus* formulation more effective against *Sitophilus oryzae* than several botanical leaf powders tested under the same conditions. Kalita et al. (2026) also documented reduced rice seed damage from *S. oryzae* following a locally derived *Polygonum hydropiper* leaf-powder treatment in traditional stores. These findings support further evaluation but do not justify transferring experimental doses to other species without validation and appropriate registration.

7. Inert dusts and microbial biological control

Diatomaceous earth is an abrasive, adsorptive mineral powder that disrupts the insect cuticle and promotes water loss. Its activity varies with insect species, formulation, dose and humidity; it may also produce dust-handling challenges. As with botanicals, assess its effects on seed flowability, germination, and field emergence before seed-lot adoption. Wakil et al. (2024) found that combinations of *Metarhizium robertsii*, diatomaceous earth and an insecticide controlled several stored-wheat pests more effectively than individual treatments. More recently, Kamboj et al. (2026) reported strong suppression of *Callosobruchus maculatus* in stored green gram using a salicylic-acid-infused diatomaceous earth composite while maintaining germination. Neither result establishes a universal seed treatment: broader testing is required. Entomopathogenic fungi, such as *Beauveria bassiana* and *Metarhizium anisopliae*, represent another potential tool. Temperature, humidity, spore viability, insect susceptibility, and compatibility with packaging or other treatments influence their effectiveness. Anuradha and Bera (2025) examined entomopathogens and diatomaceous earth in stored paddy; one combined treatment gave high mortality of *R. dominica* and lower seed damage, but germination after 12 months was only 64.67%. This illustrates why favourable insect mortality and acceptable planting-seed quality must be evaluated independently. Biocontrol agents should not replace adequate drying and sanitary storage.

8. Improved bio-based coatings and controlled release

Seed coatings containing biopolymers can improve adhesion and slow the release of volatile botanical ingredients. Wu and Kong (2026) evaluated a chitosan–eugenol coating in stored

maize and reported less insect damage and higher germination than untreated seed after 12 months. The experiment offers promising proof of concept for multifunctional seed protection, though efficacy, application uniformity, cost, worker exposure and subsequent field performance require replication. Encapsulation may reduce volatility and improve formulation stability, but environmental fate, seed safety and field performance must be assessed before routine use.

8.1. Reading experimental evidence critically

An insect-protection claim is strongest when a treatment is evaluated against untreated and suitable reference controls with equivalent initial seed quality. Adult mortality may occur quickly, whereas insect progeny and the physiological consequences of exposure become apparent only after weeks or months. Furthermore, results from a single relative humidity or a single pest population may not hold under tropical warehouse conditions. Studies should therefore report dose, method of application, pest species and life stage, exposure time, seed moisture and storage duration. A statistically significant decline in insect damage has limited practical value if the treated lot no longer meets its germination standard. Comparisons should also recognize that a botanical powder, an essential-oil coating and a microbial agent work by different mechanisms. Combining them without compatibility testing can cause antagonism, reduce microbial viability, increase phytotoxicity, or reduce protection. Test their roles best as components of a broader storage system rather than as stand-alone substitutes for clean seed and appropriate packaging.

9. Monitoring, resistance and integrated decision-making

Regular surveillance is essential even when preventive measures are used. Visual examination, representative sampling, insect traps and monitoring of seed moisture and storage temperature help identify conditions that favour rapid infestation. Pheromone lures can help detect activity of selected stored-product insects, although trap catches do not directly quantify infestation within individual seed lots. Acoustic and imaging methods may help detect hidden infestation, but affordability and field reliability require evaluation. Host-plant resistance is another preventive option. In original choice experiments, Marcos et al. (2025) reported significant differences among maize genotypes in feeding preference and oviposition by *Sitophilus zeamais*. Such genotypic comparisons indicate potential antixenosis, but they alone cannot establish that all planting-seed quality traits are preserved. For crop improvement, select for resistance to stored-seed pests without sacrificing germination, agronomic performance, or

traits farmers value. A seed-focused integrated pest management (IPM) plan has four stages: (i) receive clean, identifiable lots and establish baseline quality; (ii) dry and store under conditions suited to the crop; (iii) monitor insects and the storage environment; and (iv) intervene only with a validated, authorised treatment. Where chemical fumigation is necessary, it must be undertaken by qualified personnel under applicable regulations. Treatment choice must consider registered uses for planting seed, resistance management, re-entry and aeration requirements, seed moisture and possible phytotoxicity. Food-grain pesticide guidance must not be assumed suitable for sowing material. Resistance management, authorized use, and seed safety remain important when considering chemical treatments.

10. Evaluating resilience without sacrificing seed quality

Protection studies should measure insect mortality and progeny, as well as initial and final germination percentage, normal seedlings, seedling vigour, moisture, seed damage, and mass loss. Results from a single laboratory endpoint may overestimate practical protection. Better trials compare treated and untreated lots with the same initial seed quality, include both infested and uninfested controls, and track outcomes over realistic storage periods. Post-storage emergence tests and small field trials help determine whether germination advantages translate into establishment. Comparative studies should report cost, labour, packaging reuse, local availability, and safe disposal so effective techniques are also economically and environmentally realistic.

11. Research gaps and future directions

Further studies should establish crop-specific thresholds for safe moisture and temperature, quantify protection under fluctuating tropical environments, and test botanicals and entomopathogens across multiple seed lots and insect species. Mechanistic work is needed to determine whether repeated exposures to plant volatiles or dusts influence the embryo, membrane integrity and reserve mobilisation. Long-term trials should examine seed-coating compatibility with hermetic packaging, varietal resistance, and routine quality testing. Affordable monitoring systems and co-designed smallholder trials are important priorities, as are assessments of packaging durability, reuse and environmental impacts.

12. Conclusion

Resilient seed protection depends on prevention and timely decisions rather than any single insecticidal treatment. Clean seed, crop-appropriate drying, sound storage structures and sealed packaging form the first line of defence. Botanicals, biocontrol agents, inert dusts and advanced

coatings may offer additional options where their insecticidal activity and seed safety have both been demonstrated. Integrating surveillance with repeated germination and vigour testing provides the clearest route to preserving planting value, reducing losses and strengthening seed system resilience.

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NANO PLANT-BASED BOTANICAL DERIVATIVES FOR SUSTAINABLE WEED MANAGEMENT IN MODERN AGRICULTURE

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Abstract

Weed infestation is a major challenge in agricultural production, causing substantial crop yield losses and increasing reliance on synthetic herbicides. Although conventional herbicides provide effective weed control, their excessive use has led to environmental pollution, herbicide resistance, and adverse effects on non-target organisms. In this context, nano plant-based botanical derivatives have emerged as an innovative and sustainable alternative for eco-friendly weed management. These nano-bioherbicides consist of nanoparticle-formulated plant extracts, essential oils, and allelochemicals designed to improve the effectiveness, stability, solubility, and controlled release of naturally occurring herbicidal compounds. Several botanical derivatives, including nonanoic acid, citral derived from lemongrass, thymoquinone from black cumin, eucalyptus oil, thyme oil, peppermint oil, citronella oil, and *Artemisia* extracts, exhibit strong phytotoxic and allelopathic properties that inhibit weed seed germination, root elongation, and plant growth. The incorporation of nanotechnology into these natural products through nano-emulsions, nano-capsules, and chitosan-based delivery systems significantly enhances their bioavailability, target specificity, and persistence while minimizing the quantity required for field application. Such nano-formulations facilitate efficient penetration of active compounds into weed tissues and enable their gradual release, resulting in prolonged weed suppression and reduced environmental contamination. Furthermore, nano-botanical herbicides are biodegradable and environmentally safe, contributing to lower chemical residues in soil and water ecosystems. Their use supports the principles of sustainable agriculture by reducing dependence on synthetic chemicals and promoting ecological balance. Therefore, the integration of nanotechnology with plant-derived bioherbicides represents a promising strategy for efficient, cost-effective, and environmentally responsible weed management, contributing to enhanced crop productivity, resource conservation, and long-term agricultural sustainability.

Keywords: Bio-herbicides, Botanical derivatives, Environmental conservation, Prolonged action

ENGINEERED BIOCHAR-MICROBE CONSORTIA: ENHANCING CLIMATE-RESILIENT CROP IMMUNITY AGAINST SOIL-BORNE PATHOGENS

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Abstract

Soil-borne pathogens severely limit global crop productivity, a challenge increasingly intensified by climate-driven agricultural stresses. Conventional chemical management strategies threaten soil health and biodiversity, underscoring the urgent need for sustainable, ecologically sound crop protection alternatives. This study investigates a novel soil-driven innovation: the development and application of engineered biochar-microbe consortia designed to suppress phytopathogens while concurrently bolstering plant defences.

By functionalizing agricultural waste-derived biochar at the nano-scale via physical and chemical modifications, we optimized the carbon matrix's surface area, porosity, and surface functional groups. This engineered framework serves as a protective, nutrient-rich carrier for a targeted consortium of beneficial biocontrol agents, specifically *Pseudomonas fluorescens* and *Trichoderma harzianum.* Rhizosphere dynamics were evaluated to monitor microbial survival, root colonization, and pathogen suppression under simulated pathogen pressure.

Our findings demonstrate that the nano-engineered biochar significantly enhances the persistence and metabolic activity of the microbial consortium compared to raw biochar or direct soil inoculation. The structural modifications facilitated a controlled release of biochemical signals, altering root exudate profiles to actively recruit beneficial microbes while disrupting pathogen chemotaxis. Furthermore, biochemical analyses indicated a marked upregulation of defence-related enzymes (peroxidase and polyphenol oxidase) within the host plant, confirming the activation of Induced Systemic Resistance (ISR). This research highlights the potential of nano-scale soil management innovations to shift agricultural paradigms, offering a robust, dual-action biothreat management strategy that secures crop protection and enhances climate resilience without ecological degradation.

Keywords: Engineered Biochar, microbial consortia, induced systemic resistance

EVALUATION OF ANTAGONISTIC MICROORGANISMS FOR SUSTAINABLE MANAGEMENT OF FOOT ROT IN BRINJAL (*Solanum melongena* L.) CAUSED BY *Sclerotium rolfsii* Sacc.

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Abstract

Brinjal (*Solanum melongena* L.) foot rot incited by *Sclerotium rolfsii* (Sacc.) is a destructive and widely prevalent soil-borne disease, particularly severe under tropical and subtropical agro-climatic conditions where elevated temperature and soil moisture favor pathogen proliferation and sclerotial survival. The present investigation aimed to develop an eco-intensified and sustainable disease management strategy through the integration of native rhizosphere-derived antagonistic microorganisms and organic soil amendments (oil cakes) for effective suppression of foot rot in brinjal. A roving survey conducted during 2018–2019 across major brinjal-growing districts of Tamil Nadu, namely Coimbatore, Cuddalore, Krishnagiri, Namakkal, and Salem, revealed disease incidence ranging from 11.33 to 29.05%, confirming its widespread distribution and economic significance. Ten isolates of *S. rolfsii* were isolated and morphologically characterized on Potato Dextrose Agar (PDA). Among these, isolate I6 exhibited the highest virulence with a Percent Disease Index (PDI) of 73.22%. Standardization of inoculum production demonstrated that sorghum grain substrate at 4 g plant^{-1} was the most reliable and reproducible method for artificial disease induction under experimental conditions. *In vitro* antagonistic assays indicated that native isolates of *Pseudomonas fluorescens* (I6) and *Bacillus subtilis* (I6) significantly suppressed the radial mycelial growth of *S. rolfsii*, recording maximum inhibition of 79.32% and 83.38%, respectively. Furthermore, culture filtrates at 40% concentration resulted in complete inhibition of pathogen growth, suggesting the involvement of diffusible antifungal metabolites. Among the organic amendments evaluated, neem cake at 20% concentration was highly effective, restricting mycelial growth to 6.12 mm and achieving 93.21% inhibition of the pathogen. Under pot conditions, the integrated application of *T. harzianum* THS (ST @ 6 g/kg + SA @ 2.5 kg/ha)+ *P. fluorescens* PFS (ST @ 12 g/kg + SA@ 2.5 kg/ha)+ *B. subtilis* BSS (ST @ 12 g/kg + SA@ 2.5 kg/ha)+ Neem cake (SA @ 50 g/pot (T8) was the most effective, recording the lowest disease incidence (12.23%) and the highest disease reduction (76.88%). Under field conditions, the combined application T8 (*T. harzianum* THS (ST @ 6 g/kg + SA @ 2.5 kg/ha)+ *P. fluorescens* PFS (ST @ 12 g/kg + SA@

2.5 kg/ha)+ *B. subtilis* BSS (ST @ 12 g/kg + SA@ 2.5 kg/ha)+ Neem cake (SA @ 2.5 kg/ha) significantly reduced foot rot incidence and enhanced yield performance in field trial. This treatment recorded a mean disease incidence of 8.69% with 66.35% reduction over control. In terms of yield attributes, T8 resulted in the highest plant height (130.87 cm), number of fruits per plant (23.05), and highest fruit yield (30.21 t/ha) clearly outperforming the untreated control. The synergistic integration of plant growth-promoting rhizobacteria (PGPR) with neem cake demonstrated substantial potential as an environmentally safe, residue-free, and sustainable alternative for the management of brinjal foot rot, supporting eco-intensified crop protection strategies in tropical production systems.

Keywords: Brinjal, foot rot, bio-agents, disease incidence, plant growth promotion and yield parameters

EFFECT OF IRRIGATION AND FERTIGATION LEVELS ON GROWTH AND YIELD OF GROUNDNUT (*Arachis hypogaea* L.) UNDER MICRO SPRINKLER IRRIGATION

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Abstract

Groundnut (*Arachis hypogaea* L.) is an important oilseed crop whose productivity is influenced by irrigation management and nutrient availability. A field experiment was conducted during summer 2026 at the College Farm, SRM College of Agricultural Sciences, SRM Institute of Science and Technology, Baburayanpettai, Chengalpattu, Tamil Nadu, using groundnut variety GG 7 to determine the optimum irrigation and fertigation levels under micro sprinkler irrigation. The experiment was laid out in a Randomized Block Design with ten treatments and three replications. The treatments comprised T_1: micro sprinkler fertigation (MSF) with 125% recommended dose of fertilizer (RDF) @ 125% crop evapotranspiration (ETc); T_2: MSF with 125% RDF @ 100% ETc; T_3: MSF with 125% RDF @ 75% ETc; T_4: MSF with 100% RDF @ 125% ETc; T_5: MSF with 100% RDF @ 100% ETc; T_6: MSF with 100% RDF @ 75% ETc; T_7: MSF with 75% RDF @ 125% ETc; T_8: MSF with 75% RDF @ 100% ETc; T_9: MSF with 75% RDF @ 75% ETc; and T_{10}: drip fertigation with 100% RDF @ 125% ETc. Among the treatments, T_1 recorded the highest plant height (50.3 cm), dry matter production (5174 kg/ha), leaf area index (4.20), root length (24.1 cm), and nitrogen, phosphorus and potassium uptake. It also produced the highest pod yield (2529 kg/ha) and haulm yield (4459 kg/ha), remaining statistically comparable with T_4 for yield. Protein and oil contents were not significantly influenced by the treatments. T_3 recorded the highest water use efficiency (4.53 kg/ha-mm) and water productivity (0.453 kg/m^3), demonstrating the advantage of deficit irrigation in improving water productivity. Economically, T_1 achieved the highest gross return (₹2,53,632/ha), net return (₹1,68,576/ha) and benefit–cost ratio (2.98). Therefore, MSF with 125% RDF @ 125% ETc was the most productive and profitable treatment for maximizing groundnut productivity under the experimental conditions.

Key words: Groundnut, Micro-sprinkler fertigation, growth and yield

OPTIMIZING ROW SPACING AND EMITTER DISCHARGE RATE IN SUBSURFACE DRIP IRRIGATION FOR IMPROVING GROWTH, YIELD AND WATER PRODUCTIVITY OF MAIZE (*Zea mays* L.)

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Abstract

A field experiment entitled "Optimizing Row Spacing and Emitter Discharge Rate in Subsurface Drip Irrigation for Maize (*Zea mays* L.)" was conducted during summer (February–May 2026) at the College Farm, SRM College of Agricultural Sciences, Baburayanpettai, Chengalpattu, Tamil Nadu, to evaluate the effects of row spacing and emitter discharge rate on maize growth, physiological characteristics, yield, soil moisture dynamics, nutrient uptake and water productivity. The experiment was laid out in a Randomized Block Design with three replications and eight treatments: T_1, 30/90 cm spacing with 2 lph under subsurface drip irrigation (SDI); T_2, 45/75 cm spacing with 2 lph under SDI; T_3, 60/60 cm spacing with 2 lph under SDI; T_4, 30/90 cm spacing with 4 lph under SDI; T_5, 45/75 cm spacing with 4 lph under SDI; T_6, 60/60 cm spacing with 4 lph under SDI; T_7, surface drip irrigation with 30/90 cm spacing and 4 lph; and T_8, conventional irrigation.

Among the treatments, T_1 recorded the highest plant height, reaching 215.40 cm at harvest, whereas T_2 recorded the highest stem girth, leaf area index, dry matter production (16,068 kg/ha at harvest), crop growth rate, relative growth rate, SPAD chlorophyll index and relative water content. T_2 also recorded the highest yield attributes, grain yield, cob yield, green fodder yield and nutrient uptake, followed by T_5. Conventional irrigation recorded the highest root length, root volume and root dry weight but the lowest overall crop productivity. Subsurface drip irrigation maintained favourable soil moisture conditions within the active root zone and saved approximately 23.7% of irrigation water compared with conventional irrigation. T_2 also recorded the highest water use efficiency and water productivity. Therefore, subsurface drip irrigation with 45/75 cm row spacing and a 2 lph emitter discharge rate was identified as the most effective treatment for improving maize productivity and conserving irrigation water under the agro-climatic conditions of Chengalpattu, Tamil Nadu.

Key words: Subsurface drip irrigation, Row spacing, Emitter discharge rate, Water use efficiency, Maize productivity

EFFECT OF NUTRIENT LEVELS AND BIOFERTIGATION ON GROWTH, YIELD AND NUTRIENT UPTAK OF BLACK GRAM (*Vigna mungo* L.) UNDER DRIP IRRIGATION

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Abstract

A field experiment was conducted during summer 2026 at the College Farm, SRM College of Agricultural Sciences, SRM Institute of Science and Technology, Baburayanpettai, Chengalpattu, Tamil Nadu, to evaluate the effects of nutrient levels and biofertigation on the growth, yield, nutrient uptake, water-use efficiency and economics of black gram (Vigna mungo L.) variety VBN 11 under drip irrigation. The experiment was laid out in a Randomized Block Design with nine treatments and three replications. The treatments comprised T_1: 25% recommended dose of nitrogen (RDN) with Rhizobium and fish amino acid (FAA); T_2: 50% RDN with Rhizobium and FAA; T_3: 25% recommended dose of phosphorus (RDP_2O_5) with phosphate-solubilizing bacteria (PSB) and fulvic acid (FA); T_4: 50% RDP_2O_5 with PSB and FA; T_5: 25% recommended dose of potassium (RDK_2O) with potassium-solubilizing bacteria (KSB) and humic acid (HA); T_6: 50% RDK_2O with KSB and HA; T_7: 25% recommended dose of fertilizer (RDF) with Rhizobium, PSB, KSB, FAA, FA and HA; T_8: 50% RDF with all six biofertilizers and bioformulations; and T_9: farmer's practice with 100% RDF through furrow irrigation. Among the treatments, T_8 recorded the highest plant height (45.83 cm), dry matter production (3387 kg/ha), number of nodules per plant (38.89) and leaf area index (6.88). It also produced the highest grain yield (1479 kg/ha) and haulm yield (2413 kg/ha), remaining statistically comparable with T_2. Nutrient uptake and post-harvest available soil nitrogen, phosphorus and potassium were also highest under T_8, whereas nutrient-use efficiency was highest under T_7. Drip-fertigated treatments saved 26.68% of irrigation water compared with farmer's practice. T_8 recorded the highest water-use efficiency (4.84 kg/ha-mm), water productivity (0.48 kg/m³), gross income (₹1,32,954/ha), net income (₹87,093/ha) and benefit–cost ratio (2.90). Therefore, biofertigation with 50% RDF and a combination of beneficial microorganisms and bioformulations was identified as an effective strategy for improving

black gram productivity, resource-use efficiency, soil fertility and profitability while reducing dependence on inorganic fertilizers.

Keywords: Biofertigation, Black gram, Drip irrigation, Nutrient-use efficiency, Water productivity

SOIL APPLIED BIOPESTICIDES FOR TERMITE MANAGEMENT AND LEAF YIELD PROTECTION IN G4 MULBERRY

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Abstract

Termites damage mulberry roots and basal stems, reducing plant survival, vegetative growth and leaf availability for silkworm rearing. Soil applied biopesticides offer potential alternatives for termite management in sustainable sericulture. A field experiment was conducted on G4 mulberry at the SRM Mulberry Garden, Department of Entomology, SRM College of Agricultural Sciences, Baburayenpettai, Chengalpattu, Tamil Nadu, during 2024–2026, covering two crop cycles. Eight treatments were evaluated in a randomized block design with three replications. Treatments comprised *Metarhizium anisopliae* at 2.5 kg/ha, *Beauveria bassiana* at 2.5 kg/ha, neem cake at 500 kg/ha, each fungus combined with neem cake, both fungi combined, both fungi combined with neem cake, and an untreated control. Individual component doses were maintained in all combinations. Fungal formulations contained a nominal concentration of 1×10^8 conidia/g, and viability and compatibility were assessed before application. Treatments were applied to the root zone, with equivalent carrier inputs and irrigation maintained across plots. Observations included termite infestation, plant damage, plant survival, shoot development, marketable leaf yield and treatment economics. Combined application of *M. anisopliae* and *B. bassiana* at 2.5 kg/ha each with neem cake at 500 kg/ha recorded the greatest termite suppression, followed by both fungi combined at 2.5 kg/ha each and *B. bassiana* alone at 2.5 kg/ha. Neem cake alone was the least effective among the biopesticide treatments. These findings identify the combination of both fungi with neem cake as a promising treatment for termite management in G4 mulberry.

Keywords: G4 mulberry; termites; *Metarhizium anisopliae*; *Beauveria bassiana*; neem cake.

ANTIXENOSIS, ANTIBIOSIS AND PHYSICAL DEFENCE MECHANISMS OF RESISTANCE TO THE SPOTTED POD BORER, *Maruca vitrata*, IN SELECTED GREEN GRAM GENOTYPES

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Abstract

The spotted pod borer, *Maruca vitrata*, damages green gram flowers and pods, reducing grain yield and quality. Identifying host plant resistance mechanisms can support the selection of promising genotypes for sustainable pest management. This research framework evaluates antixenosis, antibiosis and physical defence traits in five green gram genotypes at SRM Valliammai Engineering College, Kattankulathur, Chengalpattu, Tamil Nadu, India, across six crop cycles during 2024–2026. Based on published evidence, WGG-42 and LGG-497 are selected as promising resistance references, TM-962 as an intermediate entry, and MGG-360 and LGG-450 as susceptible comparisons. The proposed field experiment follows a randomized block design with three replications, comprising fifteen plots per crop cycle. Antixenosis assessments include adult oviposition preference and larval settling on flowers and pods under choice conditions. Antibiosis assessments include larval survival, developmental duration, larval weight, pupal weight and adult emergence under no-choice conditions. Physical defence measurements comprise pod-wall thickness, trichome density and length, pod hardness and flower-cluster compactness. Field observations include larval incidence, flower infestation, pod damage, seed damage and grain yield. Published studies report longer larval development on WGG-42 than on MGG-360 and greater pod-wall thickness and trichome density in LGG-497 than in LGG-450. These findings justify genotype selection but do not establish a combined resistance ranking or constitute results from the proposed location.

Keywords: Green gram; *Maruca vitrata*; antixenosis; antibiosis; physical defence.

DEEP LEARNING - BASED EARLY DETECTION AND CLASSIFICATION OF PLANT DISEASES FROM LEAF IMAGES USING TRANSFER LEARNING

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Abstract

Plant diseases cause substantial losses in crop yield and quality worldwide, threatening food security and farmer livelihoods. Conventional detection relies on manual inspection by experts, which is slow, subjective, and often impractical for large-scale farming. This paper presents a deep learning-based framework for the early prediction and classification of plant diseases from leaf images. The proposed approach uses a convolutional neural network (CNN) with transfer learning to extract discriminative features from images in the PlantVillage dataset, which covers [X] crop species and [Y] disease classes. Preprocessing steps, including resizing, normalization, and data augmentation (rotation, flipping, and brightness adjustment), were applied to improve generalization and reduce overfitting. The model was trained and evaluated against baseline architectures such as VGG16, ResNet50, and MobileNetV2 using accuracy, precision, recall, and F1-score. Experimental results show that the proposed model achieves an accuracy of [XX.X]%, outperforming the baselines while remaining computationally efficient enough for deployment on mobile and edge devices. The framework can be integrated into a mobile application to give farmers real-time diagnosis and treatment recommendations, enabling timely intervention and reducing pesticide misuse. This work demonstrates the potential of artificial intelligence to support precision agriculture and sustainable crop management.

Key words: plant disease detection, deep learning, convolutional neural network, transfer learning, precision agriculture, image classification

INNOVATIONS IN AGRICULTURAL AND BIOLOGICAL SCIENCES FOR SUSTAINABLE CROP PROTECTION

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Abstract

Agriculture plays a vital role in ensuring global food security, but crop production faces increasing challenges from insect pests, plant diseases, weeds, and climate change. Conventional crop protection methods often depend heavily on chemical pesticides, which may negatively affect the environment, biodiversity, and human health. Therefore, innovative and sustainable approaches are essential for improving crop productivity while maintaining ecological balance. Recent advancements in agricultural and biological sciences, including integrated pest management (IPM), biological control agents, biopesticides, nanotechnology, precision agriculture, artificial intelligence, agricultural drones, and molecular techniques, offer promising solutions for effective crop protection. These innovations help in the early detection of pests and diseases, targeted application of crop protection inputs, reduction of pesticide residues, and conservation of beneficial organisms. Furthermore, integrating traditional agricultural knowledge with modern scientific technologies can enhance resource-use efficiency and strengthen the resilience of agricultural systems. This abstract highlights the importance of adopting eco-friendly, economically viable, and technology-driven crop protection strategies to promote sustainable agriculture, safeguard biodiversity, and ensure long-term food security.

Keywords: Sustainable agriculture, Crop protection, Integrated pest management, Biological control, Biopesticides, Precision agriculture.

RESILIENCE STRATEGIES FOR SUSTAINABLE AGRICULTURE, CROP HEALTH AND PLANT PROTECTION

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Abstract

Sustainable agriculture is essential for ensuring global food security, maintaining ecosystem stability, and addressing the growing challenges posed by climate change, emerging pests and diseases, soil degradation, and declining natural resources. Developing resilient agricultural systems requires integrated strategies that enhance crop health, strengthen plant protection, and improve the long-term sustainability of agricultural production. This paper explores the role of climate-resilient farming practices, integrated pest management (IPM), biological control, crop diversification, conservation agriculture, soil health management, and precision agriculture in promoting sustainable crop production. The integration of resistant crop varieties, beneficial microorganisms, biopesticides, and advanced monitoring technologies can reduce dependence on synthetic agrochemicals while minimizing environmental risks and improving crop productivity. Furthermore, the adoption of agroecological approaches, efficient water management, and data-driven decision-making can enhance the ability of farming systems to withstand biotic and abiotic stresses. Strengthening the connection between scientific research, agricultural extension services, and farmer participation is also crucial for implementing effective and locally adapted resilience strategies. By combining ecological principles with innovative technologies and sustainable plant protection practices, agricultural systems can achieve improved crop health, reduced production losses, and enhanced resource-use efficiency. Ultimately, a holistic and integrated approach to agricultural resilience can contribute to environmental conservation, economic stability for farmers, and sustainable food production under changing climatic and ecological conditions.

Keywords: Sustainable agriculture, agricultural resilience, crop health, plant protection, integrated pest management, climate change, biological control, soil health, precision agriculture, sustainable crop production.

ADVANCES IN SEED QUALITY ENHANCEMENT, SEED HEALTH AND SUSTAINABLE CROP PRODUCTION

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Abstract

Seed quality is a fundamental determinant of successful crop establishment, productivity and agricultural sustainability. High-quality seeds possess superior genetic purity, physical purity, physiological vigour and seed health, enabling uniform germination, rapid seedling establishment and improved crop performance under diverse environmental conditions. Recent advancements in seed science and technology have introduced innovative approaches for enhancing seed quality, including seed priming, seed coating, seed pelleting, biological seed treatments, nanotechnology, cold plasma treatment, precision seed sorting and molecular seed health assessment. These technologies improve seed performance by strengthening metabolic activities, enhancing antioxidant defence mechanisms, reducing seed-borne pathogens and increasing tolerance to abiotic stresses. In addition, the integration of beneficial microorganisms, sustainable seed treatments and advanced diagnostic techniques contributes to environmentally responsible crop production. Seed health management has gained particular importance because seed-borne pathogens can reduce germination, establish infections during early crop growth and facilitate the spread of diseases across agricultural regions. The adoption of integrated seed quality enhancement strategies, combined with climate-resilient crop varieties and precision agriculture, provides opportunities to improve resource-use efficiency and agricultural productivity. This chapter discusses the major components of seed quality, recent technological developments in seed enhancement, sustainable approaches to seed health management and their contributions to resilient and sustainable crop production.

Keywords: Seed quality enhancement, seed priming, seed health, seed coating, biological seed treatment, sustainable agriculture, crop productivity.

Introduction

Seeds are the basic biological input in agricultural production and play a crucial role in determining crop establishment, growth, development and final yield. The productivity of agricultural crops depends not only on the genetic potential of cultivated varieties but also on the physiological and health status of the seeds used for sowing. High-quality seeds ensure rapid and uniform germination, vigorous seedling growth, better crop establishment and improved adaptability to environmental stresses. In contrast, poor-quality seeds may exhibit delayed germination, reduced field emergence, abnormal seedlings and increased susceptibility to diseases, ultimately affecting crop productivity.

Seed quality is a multidimensional concept involving genetic, physical, physiological and seed health attributes. Genetic quality ensures varietal identity and genetic purity, whereas physical quality determines the absence of inert matter, weed seeds and other crop seeds. Physiological quality is associated with germination capacity, seed vigour, viability and storability. Seed health refers to the absence of seed-borne pathogens and harmful organisms that can negatively influence seed germination and crop development. These components collectively determine the suitability of seed lots for commercial cultivation.

Conventional seed quality improvement practices primarily involve seed cleaning, grading, drying, storage and chemical seed treatment. However, increasing environmental concerns, emerging plant diseases, climate variability and the need to reduce chemical inputs have encouraged the development of advanced seed enhancement technologies. Seed priming, microbial inoculation, polymer coating, nanotechnology, cold plasma treatment and precision-based seed sorting have emerged as promising approaches for improving seed performance.

Modern seed enhancement technologies also contribute to sustainable crop production by improving nutrient-use efficiency, reducing seedling mortality, supporting biological disease management and promoting uniform crop establishment. Therefore, integrating advanced seed quality enhancement techniques with effective seed health management is essential for developing productive, resource-efficient and climate-resilient agricultural systems.

MAJOR COMPONENTS OF SEED QUALITY

Seed quality is determined by several interrelated characteristics that influence the performance of seeds from sowing to crop establishment. Understanding these components is essential for selecting appropriate seed enhancement and quality management strategies.

1 Genetic Quality

Genetic quality refers to the maintenance of varietal identity, genetic purity and heritable characteristics of a seed variety. It ensures that the plants produced from a particular seed lot express the expected morphological, physiological and agronomic characteristics. Genetic contamination may occur through unwanted cross-pollination, mechanical mixtures, mutations and improper handling during seed production, processing and storage. Maintenance of genetic purity requires appropriate isolation distances, rouging of off-type plants, controlled pollination, proper harvesting and separate processing of seed lots. Molecular markers, DNA fingerprinting and variety-specific molecular assays provide additional opportunities for identifying genetic contamination and verifying varietal identity. These techniques are particularly useful in hybrid seed production and genetic purity testing.

2 Physical Quality

Physical quality represents the physical composition and cleanliness of a seed lot. It includes the proportion of pure seeds, inert matter, other crop seeds and weed seeds. Physical impurities may interfere with mechanical sowing, reduce seed distribution uniformity and introduce undesirable plant species into cultivated fields. Modern seed processing facilities employ air-screen cleaners, gravity separators, indented cylinder separators, magnetic separators and optical sorting equipment to improve physical purity. These machines separate seeds according to size, shape, density, weight, surface characteristics and colour. Proper grading also improves the uniformity of seed lots and facilitates precision sowing.

3 Physiological Quality

Physiological quality determines the ability of seeds to germinate, produce normal seedlings and establish successfully under field conditions. It is generally evaluated through seed viability, germination percentage, seed vigour and moisture content. Seed vigour is particularly important because two seed lots with similar standard germination percentages may differ considerably in their field emergence and seedling growth. Physiologically vigorous seeds exhibit rapid water absorption, effective membrane repair, efficient mitochondrial activity and improved reserve mobilisation during germination. Seed deterioration during storage results in membrane damage, oxidative stress, reduced enzyme activity and loss of germination potential. Appropriate drying, moisture regulation, temperature management and suitable packaging are therefore essential for maintaining physiological quality.

4 Seed Health Quality

Seed health refers to the presence or absence of pathogenic microorganisms and other harmful biological agents associated with seeds. Fungi, bacteria, viruses and certain nematodes can be transmitted through contaminated seeds. Seed-borne pathogens may cause seed rot, damping-off, seedling blight, systemic infections and reduced plant establishment. Seed health testing is important for identifying contaminated seed lots before distribution and cultivation. Conventional methods such as blotter tests, agar plate methods and seedling symptom observation are widely used. Advanced diagnostic techniques, including polymerase chain reaction (PCR), quantitative PCR, enzyme-linked immunosorbent assay (ELISA) and loop-mediated isothermal amplification (LAMP), enable more sensitive and rapid detection of specific pathogens.

ADVANCED SEED QUALITY ENHANCEMENT TECHNOLOGIES

Seed enhancement technologies are designed to improve seed performance beyond the quality achieved through conventional cleaning, grading and storage. These technologies modify the physiological, biochemical or physical characteristics of seeds to improve germination, vigour, stress tolerance and seedling establishment.

1 Seed Priming

Seed priming is a controlled pre-sowing hydration technique that initiates the early metabolic activities associated with germination without allowing radicle emergence. During priming, seeds absorb a regulated quantity of water, activating enzymes involved in respiration, protein synthesis, DNA repair and reserve mobilisation. Primed seeds generally exhibit faster and more uniform germination than untreated seeds under favourable and stressful environmental conditions. Seed priming enhances antioxidant enzyme activities, including catalase, superoxide dismutase and peroxidase, which protect cellular components against oxidative damage. It also supports membrane repair and improves mitochondrial functioning during germination. However, priming duration, temperature, solution concentration and drying conditions must be standardised for individual crop species to avoid seed deterioration.

2 Seed Coating and Film Coating

Seed coating involves applying a thin layer of materials onto the seed surface to improve handling, protect seeds and facilitate the delivery of beneficial substances. Modern coating formulations may contain polymers, nutrients, plant growth regulators, biological agents and

protective compounds. Film coating produces a thin, uniform layer without significantly altering the original seed shape or size. It improves seed handling, reduces dust formation and facilitates the application of accurately measured treatment materials. Encrusting increases seed size through the addition of coating materials, while pelleting substantially modifies seed shape to obtain uniform, round or mechanically suitable planting units.

Biodegradable polymers, starch, cellulose, chitosan, alginate and natural gums are increasingly investigated as environmentally compatible coating materials. These substances provide a carrier system for delivering nutrients and beneficial microorganisms while reducing dependence on persistent synthetic polymers. Seed coating also offers opportunities for precision nutrient delivery. For example, micronutrients incorporated into coating formulations can become available near the developing radicle and emerging seedling. Similarly, microbial coatings can introduce beneficial rhizobacteria and fungal antagonists into the seed microenvironment. The effectiveness of coating materials depends on their adhesion, water permeability, mechanical strength, compatibility with seed physiology and storage stability.

3 Seed Pelleting

Seed pelleting is a seed enhancement technique in which small, irregular or lightweight seeds are enclosed within a coating material to produce uniform-sized pellets. This technology is particularly useful for vegetable, flower and forage crops, where small seed size makes mechanical sowing difficult. Pelleting improves seed placement, sowing accuracy and spacing uniformity. It facilitates the use of precision planters and reduces the requirement for manual thinning. The pellet formulation generally consists of inert fillers, binders, colouring agents and, where appropriate, nutrients or biological materials. Materials such as diatomaceous earth, talc, calcium carbonate, clay, starch and other biodegradable substances are used as pellet components. The formulation should permit sufficient water penetration, oxygen exchange and timely seedling emergence. Excessively compact or water-resistant pellets may delay germination and reduce seedling establishment.

4 Biological Seed Enhancement

Biological seed enhancement involves the application of beneficial microorganisms to improve plant growth and protect developing seedlings against pathogens. Plant growth-promoting rhizobacteria (PGPR), phosphate-solubilising bacteria, nitrogen-fixing bacteria and beneficial fungi are widely investigated for this purpose. Species of *Bacillus, Pseudomonas, Azospirillum,*

Rhizobium and *Trichoderma* are important microbial resources in seed treatment formulations. Their beneficial activities include nutrient solubilisation, biological nitrogen fixation, siderophore production, phytohormone synthesis and pathogen suppression. Some beneficial microorganisms produce indole-3-acetic acid, gibberellins and other plant growth regulators that stimulate root development and improve nutrient absorption. Certain bacterial strains produce siderophores that bind iron and restrict its availability to competing pathogens. Antagonistic fungi such as Trichoderma suppress soil-borne pathogens through competition, antibiosis, mycoparasitism and induced systemic resistance. Biological seed treatment is particularly valuable in sustainable crop production because it can reduce dependence on synthetic pesticides and improve the biological functioning of the rhizosphere. However, microbial viability, formulation compatibility, storage conditions and crop-specific effectiveness must be evaluated before commercial application.

5 Nanotechnology-Based Seed Enhancement

Nanotechnology offers new opportunities for improving seed germination, nutrient delivery and stress tolerance through the application of engineered nanomaterials. Nanoparticles of zinc oxide, iron oxide, silicon dioxide and other materials have been investigated for their potential to improve seed physiological activities. Nanopriming involves exposing seeds to appropriately formulated nanoparticle suspensions before sowing. At suitable concentrations, these materials may influence water absorption, antioxidant defence, enzyme activities and nutrient availability. Zinc oxide nanoparticles, for instance, have been investigated for their contribution to zinc nutrition and early plant development. Nano-enabled seed coatings may also facilitate controlled release of nutrients and protective substances. Their small particle size provides opportunities for improving the efficiency of active ingredients and reducing the quantity required in certain applications. However, nanoparticle effectiveness depends strongly on particle size, concentration, chemical composition, surface properties and exposure duration. Excessive concentrations may cause oxidative stress, cellular damage and reduced germination. Long-term environmental fate, soil accumulation and effects on beneficial microorganisms require careful assessment before large-scale agricultural adoption.

6 Cold Plasma Seed Treatment

Cold plasma is an emerging non-thermal physical technology used to modify seed surface characteristics and improve germination. It consists of partially ionised gas containing reactive oxygen and nitrogen species, charged particles, electrons and ultraviolet radiation. When seeds

are exposed to controlled plasma treatment, changes may occur in seed coat wettability, surface energy and chemical composition. These modifications can improve water absorption and facilitate uniform imbibition. Reactive oxygen and nitrogen species generated during treatment may also influence antioxidant defence systems, metabolic activities and germination-related signalling pathways.

Cold plasma treatment has demonstrated potential in improving seed germination, seedling vigour and resistance to certain seed-associated microorganisms. It can also reduce the need for conventional chemical seed disinfection in selected applications. The effectiveness of plasma treatment depends on exposure duration, gas composition, discharge power, treatment distance and seed moisture content. Excessive exposure may damage seed surface structures and reduce viability. Therefore, crop-specific optimisation and standardisation are necessary before routine commercial use.

SEED HEALTH MANAGEMENT AND ADVANCED PATHOGEN DETECTION

Seed health management is essential for preventing the introduction and spread of plant diseases through agricultural seed systems. Seed-borne pathogens may remain associated with seeds during storage and become active under favourable environmental conditions after sowing. Effective seed health management therefore requires a combination of disease diagnosis, preventive measures, seed treatment and quality assurance.

1 Major Seed-borne Pathogens

Seed-borne diseases are caused by fungi, bacteria, viruses and other harmful organisms associated with seeds. Fungal pathogens are responsible for several important seed and seedling diseases. Fusarium species cause seed rot, damping-off and seedling blight in different crops. Alternaria species are associated with seed discolouration, reduced germination and seedling diseases. *Colletotrichum* species cause anthracnose diseases in several agricultural and horticultural crops. *Aspergillus* and *Penicillium* species may contribute to seed deterioration during storage under unsuitable moisture and temperature conditions. Bacterial pathogens such as *Xanthomonas*, *Pseudomonas* and *Clavibacter* may be transmitted through contaminated seeds and establish infections in developing plants. Certain plant viruses are also seed-transmitted, depending on the virus and host species. Their presence in seed lots can contribute to disease dissemination and reduction in crop quality.

2 Conventional Seed Health Testing

Conventional seed health testing techniques are important for identifying seed-associated pathogens and evaluating the suitability of seed lots for cultivation. The standard blotter method involves placing seeds on moist blotting paper and incubating them under controlled conditions to encourage fungal growth. Pathogens developing on the seeds are subsequently identified through their morphological and microscopic characteristics. The agar plate method involves placing seeds on suitable culture media to isolate and identify pathogenic microorganisms. It is useful for studying fungal and bacterial contamination, although identification may require additional biochemical or molecular confirmation. The grow-out test involves sowing seeds under controlled conditions and observing the resulting seedlings for disease symptoms. This method provides information on the ability of seed-associated pathogens to produce infection in plants. These methods remain important because they provide biological evidence of pathogen development. However, they may require considerable time, specialised personnel and controlled laboratory conditions.

3 Molecular Detection of Seed-borne Pathogens

Molecular diagnostic methods have improved the speed and sensitivity of seed health testing. Polymerase chain reaction (PCR) is widely used to identify specific pathogen DNA sequences in seed samples. Quantitative PCR (qPCR) enables real-time monitoring of DNA amplification and provides information about the relative quantity of target genetic material. Reverse transcription PCR (RT-PCR) is useful for detecting RNA viruses through the conversion of viral RNA into complementary DNA before amplification. Loop-mediated isothermal amplification (LAMP) offers rapid detection under constant temperature conditions and is suitable for developing simplified diagnostic systems. ELISA is another important technique used for detecting pathogen-specific antigens, particularly in seed health testing for plant viruses. The method is based on antigen-antibody interactions and is suitable for screening relatively large numbers of samples. Advanced molecular methods should be supported by appropriate sampling, validated extraction protocols and reference controls. Molecular detection of pathogen DNA does not necessarily demonstrate that the detected organism is alive or capable of causing infection. Therefore, regulatory decisions may require confirmation using culture-based or biological assays.

4 Integrated Seed Treatment for Disease Management

Integrated seed treatment combines physical, biological and chemical methods to minimise seed-associated pathogens and protect seedlings during early development. Physical treatments include hot water treatment, controlled drying and selected non-thermal technologies. Biological treatments involve beneficial microorganisms that suppress pathogens and promote plant growth. Chemical treatments use appropriately registered fungicides and bactericides to control specific seed-associated pathogens. Seed treatment selection must consider crop species, seed sensitivity, target pathogen, treatment concentration and environmental safety. Compatibility between different treatment materials is particularly important when combining biological inoculants with chemical seed treatments. Integrated management is more effective when supported by pathogen-free seed production, field sanitation, crop rotation, proper harvesting and hygienic seed processing.

INTEGRATION OF SEED QUALITY ENHANCEMENT WITH SUSTAINABLE CROP PRODUCTION

Seed quality enhancement contributes to sustainable crop production by improving the efficiency of agricultural inputs and supporting better crop establishment. The integration of seed technologies with improved crop management practices provides opportunities to increase productivity while reducing unnecessary resource consumption.

1 Precision Sowing and Uniform Crop Establishment

Precision sowing involves the accurate placement of individual seeds at predetermined spacing and depth using specialised planting equipment. High-quality, graded and pelleted seeds improve the performance of precision planters by ensuring uniform seed distribution. Uniform crop establishment reduces competition among plants for sunlight, water and nutrients. It also facilitates mechanised intercultural operations, irrigation scheduling and harvesting. Seed grading, coating and pelleting therefore contribute indirectly to improved field management and production efficiency.

2 Improved Nutrient-use Efficiency

Nutrient-enhanced seed treatments and microbial inoculants support early nutrient acquisition and seedling development. Micronutrient priming with zinc, boron and iron can improve nutrient availability during the initial growth stages. Biological inoculants such as nitrogen-fixing bacteria and phosphate-solubilising microorganisms improve nutrient availability

through biological processes. Their application can complement soil fertilisation practices and improve nutrient-use efficiency when appropriately matched with crop requirements.

3 Improved Water-use Efficiency

Rapid and uniform germination contributes to effective crop establishment and the timely development of root systems. Priming treatments may improve seedling emergence under limited moisture conditions, although their effectiveness varies with crop species and environmental conditions. Seed enhancement technologies can be integrated with drip irrigation, precision irrigation and moisture-conservation practices to improve water-use efficiency. Improved early root development may also support better access to available soil moisture during subsequent growth stages.

4 Sustainable Crop Protection

Healthy seeds reduce the possibility of introducing seed-borne diseases into agricultural fields. The use of pathogen-free seeds, biological treatments and integrated disease management reduces the need for repeated pesticide applications during early crop development. Beneficial microorganisms applied through seed treatments may also improve rhizosphere health and support natural disease suppression. Combining seed health management with resistant cultivars, crop rotation and field sanitation provides a comprehensive approach to sustainable crop protection.

5 Seed Quality Management under Climate Variability

Climate-resilient agriculture requires seeds capable of maintaining satisfactory germination and establishment under variable environmental conditions. Seed priming, microbial treatments, suitable coating materials and improved storage technologies can contribute to greater seed performance under stress. However, seed enhancement cannot completely overcome unsuitable environmental conditions or poor crop management. Therefore, it should be considered a complementary component of an integrated climate-resilient production system.

Conclusion

Seed quality enhancement, seed health management and sustainable crop production are closely interconnected components of modern agricultural development. High-quality seeds provide the foundation for successful crop establishment, uniform plant growth and improved

productivity. Advances in seed priming, coating, pelleting, biological inoculation, nanotechnology and cold plasma treatment have expanded the possibilities for improving seed germination, vigour and tolerance to environmental stresses.

Similarly, developments in molecular diagnostics, digital imaging, hyperspectral analysis and artificial intelligence have strengthened the accuracy and efficiency of seed quality assessment and pathogen detection. These technologies enable improved identification of seed deterioration, physical defects and seed-borne pathogens, thereby supporting the production and distribution of healthy planting materials.

Sustainable seed enhancement requires the integration of environmentally compatible coating materials, beneficial microorganisms, efficient nutrient delivery systems and appropriate seed health practices. Biodegradable polymers, biological seed treatments and precision-based seed processing offer opportunities to reduce unnecessary chemical inputs and improve resource-use efficiency. Proper seed drying, packaging and storage are equally important for maintaining the physiological quality achieved through enhancement treatments.

The integration of advanced seed technologies with climate-resilient varieties, precision sowing, efficient irrigation and integrated crop protection can contribute to stable agricultural production under changing environmental conditions. Nevertheless, the successful adoption of these innovations requires crop-specific standardisation, economic evaluation, environmental safety assessment and field-level validation. Strengthening research collaboration among seed scientists, plant pathologists, microbiologists, agricultural engineers and seed industries will accelerate the development of practical technologies. Ultimately, the production and utilisation of genetically pure, physically clean, physiologically vigorous and healthy seeds will remain essential for improving agricultural productivity, conserving natural resources and ensuring sustainable food production.

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BOTANICAL-BASED APPROACHES FOR ECO-FRIENDLY MANAGEMENT OF BRINJAL SHOOT AND FRUIT BORER, *Leucinodes orbonalis* (Guenée)

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Abstract

Brinjal is one of the major vegetable crops cultivated throughout India and serves as an important source of income for small and marginal farmers. However, its productivity is considerably reduced by the brinjal shoot and fruit borer, Leucinodes orbonalis (Guenée), which causes serious damage during crop growth and fruit development. The concealed feeding habit of the larva makes effective management difficult and often results in repeated application of chemical insecticides. This emphasizes the need for safer and sustainable pest management approaches.

The present investigation was carried out to explore the insecticidal and behavioural effects of selected botanicals against L. orbonalis under laboratory conditions. Ethanol extracts of selected plant materials were prepared and tested at different concentrations against the larval stages of the pest. Larval mortality and biological responses were recorded to determine the efficacy of the treatments. The promising botanical extracts were further subjected to GC-MS analysis to identify their major phytochemical constituents. Molecular docking studies were also considered to understand the possible interaction of identified bioactive compounds with target proteins of the pest. In addition, olfactometer studies were conducted to evaluate the repellent response of L. orbonalis towards selected botanical treatments.

The study demonstrates the potential of plant-derived compounds as promising alternatives to conventional insecticides. The integration of botanical extracts, behavioural management and identification of bioactive compounds could contribute to the development of effective and environmentally compatible pest management strategies. Such approaches may help reduce pesticide dependence, minimize ecological risks and support sustainable crop protection in brinjal cultivation.

Keywords: *Leucinodes orbonalis,* Brinjal, Botanical extracts, Insecticidal activity, GC-MS, Molecular docking, Repellency, Sustainable pest management.

HONEY BEE GUT MICROBIOME: AN EMERGING BIOLOGICAL RESOURCE FOR AGROCHEMICAL STRESS MANAGEMENT AND SUSTAINABLE CROP PROTECTION

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Abstract

Agrochemical intensification poses a significant threat to pollinator health and sustainable crop production. The honey bee gut microbiome represents an important biological system involved in host nutrition, immunity and responses to environmental stress. Exposure to insecticides, herbicides and other agrochemicals can influence the composition and functional characteristics of these microbial communities. Emerging research suggests that certain gut associated bacteria exhibit pesticide tolerance and may possess metabolic capabilities involved in xenobiotic transformation. This study explores the potential of indigenous gut microorganisms associated with honey bees as a biological resource for understanding pesticide microbiome interactions. Investigating microbial diversity, pesticide tolerance and potential transformation capabilities may help identify promising bacterial taxa for further evaluation in pollinator health research. Understanding these interactions could provide new insights into microbiome mediated pollinator resilience and contribute to the development of sustainable, pollinator friendly crop protection strategies.

Key Words: Microbiome; Agrochemicals; Biodegradation; Pollinators; Pesticide Tolerance.

EMERGING FLEA BEETLE THREATS IN INDIAN AGRICULTURE: ECOLOGICAL INSIGHTS AND MICROBIAL APPROACHES FOR SUSTAINABLE MANAGEMENT

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Abstract

Flea beetles (*Phyllotreta* spp.), particularly the striped flea beetle (*Phyllotreta striolata*), represent an emerging challenge to cruciferous crop production in South India, including radish-growing regions of Tamil Nadu. Adult beetles cause characteristic shot hole damage to foliage, reducing crop quality and marketability. Increasing dependence on synthetic insecticides raises concerns about environmental contamination, insecticide resistance and adverse effects on beneficial organisms. Therefore, exploring sustainable biological management alternatives is essential. Recent research has demonstrated the potential of indigenous entomopathogenic fungi, particularly *Beauveria bassiana* and *Metarhizium anisopliae*, as promising microbial control agents against flea beetles. These fungi infect insect hosts through cuticular penetration and subsequent internal colonisation. Integrating native fungal resources with systematic pest surveillance, cultural practices and need based management could strengthen integrated pest management strategies. Such biologically based approaches offer opportunities to reduce dependence on synthetic insecticides and promote sustainable cruciferous crop production while supporting ecological resilience in agricultural ecosystems.

Key Words: Flea beetles; Biocontrol; Entomopathogens; Mycoinsecticides; IPM.

INTEGRATED PEST AND DISEASE MANAGEMENT: CLIMATE-SMART BIOLOGICAL AND DIGITAL STRATEGIES FOR RESILIENT AND SUSTAINABLE CROP PROTECTION AND FRUIT BORER, *Leucinodes orbonalis (Guenée)*

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Abstract

Global crop production is increasingly threatened by insect pests, plant pathogens and invasive species, whose incidence, distribution and severity are being reshaped by climate variability. Conventional dependence on synthetic pesticides has led to pesticide resistance, resurgence of secondary pests, loss of beneficial organisms and environmental contamination, underscoring the need for resilient and sustainable plant protection strategies. This paper reviews recent innovations that integrate biological, ecological and digital approaches to build durable crop health management systems. Key components include the use of biocontrol agents such as Trichoderma spp., Pseudomonas fluorescens, Bacillus spp., entomopathogenic fungi and nematodes, parasitoids and predators; botanical and microbial biopesticides; host plant resistance supported by marker-assisted selection and genome editing; and RNA interference-based and nano-formulated products for targeted pest and disease suppression. Molecular diagnostics, remote sensing, drones, artificial intelligence-based pest forecasting and decision-support tools further enable early detection, precision application and reduced input use. Climate-smart practices, including habitat management, pollinator conservation, crop diversification, resistant cultivars and need-based use of safer molecules, strengthen the adaptive capacity of agroecosystems under changing climatic conditions. Evidence from field studies indicates that integrated pest and disease management (IPDM) reduces chemical load, conserves natural enemies and pollinators, lowers production costs and sustains yield and farm income. However, challenges such as limited farmer awareness, inconsistent quality of bio-inputs, regulatory constraints and the lack of region-specific decision-support systems still restrict large-scale adoption. Strengthening research–extension linkages, farmer participatory validation, policy support and industry collaboration is therefore essential.

Keywords: Plant protection, Integrated pest management, Biological control, Climate resilience, Precision agriculture, Sustainability

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BIODIVERSITY-DRIVEN ECOLOGICAL PEST MANAGEMENT: STRENGTHENING CROP HEALTH AND RESILIENCE IN SUSTAINABLE RICE ECOSYSTEMS

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Abstract

The increasing dependence on synthetic insecticides in rice cultivation has raised concerns regarding pest resistance, declining populations of beneficial arthropods and disruption of agroecosystem stability. Although chemical pesticides provide rapid pest suppression, their non-target effects may interfere with natural biological control processes. Therefore, developing ecologically sustainable pest management strategies is essential for maintaining crop health while conserving beneficial insect communities. The proposed study aims to comparatively evaluate the effectiveness of different ecological pest management approaches in rice ecosystems, with particular emphasis on pest suppression, natural enemy conservation and crop productivity. Field experiments will be conducted under different pest management treatments, including conventional chemical pest management, integrated pest management (IPM), habitat-based ecological management and untreated control. Arthropod communities will be monitored periodically using sweep nets, yellow sticky traps and pitfall traps to assess the abundance, richness and diversity of insect pests, predators and parasitoids. In addition, crop damage, pest incidence and yield parameters will be recorded to determine the effectiveness of each management strategy. Diversity indices and appropriate statistical analyses will be employed to establish relationships between pest populations, beneficial arthropod communities and crop performance. The study is expected to identify management approaches that effectively suppress major insect pests while conserving beneficial arthropods and maintaining crop productivity. Integrating habitat management with biological control and need-based pesticide application may provide an ecologically balanced alternative to conventional pest management. The findings could contribute to developing location-specific, biodiversity-friendly crop protection strategies and strengthening the resilience of rice-based agricultural ecosystems. This approach may offer practical insights into reducing pesticide dependency while promoting sustainable agricultural production.

Keywords: Ecological pest management, Arthropod biodiversity, Natural enemies, Rice ecosystem, Integrated Pest Management, Crop resilience.

TOWARDS SUSTAINABLE PLANT PROTECTION: MULTI-RESIDUE ASSESSMENT OF PESTICIDES IN BRINJAL FRUITS AND AGRICULTURAL SOIL

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Abstract

The increasing dependence on synthetic pesticides for managing insect pests and diseases in vegetable production has intensified concerns regarding food safety, environmental contamination and the long-term sustainability of agricultural ecosystems. Brinjal (*Solanum melongena* L.), an economically important vegetable crop, is particularly susceptible to insect pest infestations, often resulting in frequent pesticide applications. However, inappropriate pesticide usage and inadequate adherence to recommended application practices may contribute to pesticide residue accumulation in harvested fruits and agricultural soils. Understanding the occurrence of pesticide residues across interconnected agricultural matrices is therefore essential for developing environmentally responsible plant protection strategies.

The present investigation aims to characterize pesticide residue occurrence in brinjal fruits and associated agricultural soils across nine taluks of Villupuram district, Tamil Nadu, India. A total of 18 paired samples, comprising nine brinjal fruit samples and nine *Corresponding soil samples, will be collected from selected brinjal production fields. Pesticide residues will be extracted using the QuEChERS (Quick, Easy, Cheap, Effective, Rugged and Safe) methodology and subsequently analysed using Gas Chromatography–Mass Spectrometry (GC–MS). Analytical method performance will be evaluated through appropriate validation parameters, including linearity, recovery, precision, limits of detection and quantification. The identified residues will be assessed against applicable Maximum Residue Limits (MRLs), where established, to determine their regulatory relevance. Comparative evaluation of fruit and soil residue profiles will provide preliminary insights into pesticide occurrence across the crop–soil interface.

The study is expected to establish baseline evidence on pesticide residue occurrence in brinjal production systems and highlight potential food safety and environmental concerns. By integrating analytical residue monitoring with sustainable pesticide management perspectives, this research aims to support judicious pesticide application, strengthen Integrated Pest

Management (IPM) programmes and encourage environmentally sustainable vegetable production. The findings will contribute to evidence-based plant protection practices that balance crop protection, consumer safety and agricultural ecosystem sustainability.

Keywords: *Solanum melongena*, Pesticide residue monitoring, Agricultural soil, QuEChERS, GC–MS, Food safety, Environmental contamination, Sustainable plant protection.

DEVELOPMENT OF AN INSECT PEST EARLY-WARNING SYSTEM USING REMOTE SENSING, WEATHER DATA AND GIS

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Abstract

Insect pests are among the major biological constraints affecting agricultural productivity, and their sudden population outbreaks can cause considerable economic losses to farmers. Conventional pest monitoring primarily depends on field scouting and visual observations, which are often time-consuming and spatially limited. The integration of remote sensing, meteorological data and Geographic Information Systems (GIS) provides an opportunity to develop spatially explicit and timely insect pest early-warning systems. The present proposed study aims to develop a GIS-based early-warning framework for monitoring and predicting the occurrence of brown planthopper (*Nilaparvata lugens* Stål) in rice ecosystems. Sentinel-2 satellite imagery will be used to derive vegetation indices such as Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI) and Normalized Difference Red Edge (NDRE) to assess crop vegetation conditions. Meteorological parameters, including maximum and minimum temperature, relative humidity and rainfall, will be collected from meteorological stations or gridded weather datasets. Weekly field-level pest surveillance will be conducted to record brown planthopper population density, crop growth stage and infestation levels using GPS-based sampling locations. The collected datasets will be integrated using Google Earth Engine and QGIS to analyse relationships between environmental conditions, crop health and pest population dynamics. Statistical techniques such as correlation analysis, multiple regression and time-series analysis will be employed to develop a preliminary pest-risk prediction model. The proposed framework is expected to generate spatial pest distribution maps and classify agricultural areas into low-, moderate- and high-risk zones. The study will contribute to the development of an integrated digital pest surveillance approach that can support timely pest management decisions and reduce dependence on reactive pesticide applications.

Keywords: Brown planthopper, Early-warning system, GIS, Remote sensing, Sentinel-2, Weather parameters, Pest surveillance, Pest-risk mapping.

1. INTRODUCTION

Agriculture plays an important role in ensuring food security and supporting the livelihoods of millions of people. However, crop production is continuously affected by several biotic and abiotic factors, among which insect pests are major constraints. Insect pest infestations can reduce crop growth, damage plant tissues and cause considerable yield losses when populations increase beyond economically manageable levels.

Conventional insect pest surveillance mainly depends on direct field observations, periodic scouting and farmer-based reporting. Although these methods are useful for identifying pest incidence, they may not provide sufficient spatial coverage or advance information about potential pest outbreaks.

The development of remote sensing and geospatial technologies has created new opportunities for agricultural monitoring. Satellite imagery provides information about vegetation conditions, crop growth and changes in agricultural landscapes. Sentinel-2 satellite data, with its multispectral observations and different spatial resolutions, can be used to derive vegetation indices for assessing crop conditions. The Sentinel-2 mission provides 13 spectral bands, including bands at 10 m, 20 m and 60 m spatial resolutions (European Space Agency, 2026).

Meteorological conditions also influence insect pest development, reproduction, survival and population fluctuations. Temperature, humidity, rainfall and wind conditions may affect the development and dispersal of several agricultural insect pests. Previous studies conducted in Tamil Nadu have examined relationships between weather parameters and brown planthopper incidence in rice ecosystems (Prakash and Asaf, 2024).

The brown planthopper, *Nilaparvata lugens* Stål, is an economically important sucking pest of rice. Both nymphs and adults feed on plant sap, resulting in yellowing, drying and eventual death of rice plants, a condition commonly known as hopper burn. Its population dynamics are influenced by crop growth stage, environmental conditions, crop management and natural enemies.

The integration of field-level entomological observations, satellite-derived vegetation indices and meteorological information through GIS can provide a better understanding of the spatial and temporal distribution of insect pests.

Therefore, the present study proposes the development of an insect pest early-warning system by integrating remote sensing, weather data and GIS for identifying potential brown planthopper outbreak zones in rice-growing areas.

2. REVIEW OF LITERATURE

2.1 Remote sensing in agricultural monitoring

Remote sensing has become an important technology for monitoring crop growth, vegetation conditions and agricultural land-use patterns. Multispectral satellite imagery provides information about vegetation reflectance in different spectral regions.

Sentinel-2 imagery is particularly useful for agricultural applications because it provides multispectral observations at 10 m, 20 m and 60 m spatial resolutions. Vegetation indices derived from Sentinel-2 imagery can help identify spatial variations in crop condition and vegetation development.

2.2 Influence of weather parameters on insect pest incidence

Weather conditions influence insect pest development and population fluctuations. Temperature affects insect growth, development and reproduction, whereas relative humidity and rainfall can influence survival and activity.

Prakash and Asaf (2024) investigated the influence of abiotic factors on brown planthopper incidence in rice in Cuddalore district, Tamil Nadu. Their study demonstrated that weather parameters could be useful in understanding seasonal fluctuations in brown planthopper populations.

Similarly, studies on rice planthoppers have highlighted the importance of environmental factors in understanding pest population dynamics.

2.3 GIS in insect pest surveillance

Geographic Information Systems provide tools for collecting, managing, analysing and displaying spatial information. GIS-based pest distribution mapping can help identify locations with different levels of infestation.

The integration of GPS-based field observations with environmental and satellite-derived datasets allows the preparation of spatially distributed pest-risk maps.

2.4 Need for an integrated early-warning approach

Although field surveillance, meteorological monitoring and satellite-based agricultural assessment are individually useful, their integration can provide a more comprehensive approach to pest-risk assessment.

An integrated framework combining field observations, weather parameters and satellite-derived crop information may improve the identification of potentially vulnerable agricultural areas and support timely pest management decisions.

3. OBJECTIVES

1. To monitor the occurrence and population dynamics of brown planthopper in selected rice-growing areas.
2. To analyse the relationship between meteorological parameters and brown planthopper population fluctuations.
3. To assess rice crop conditions using Sentinel-2 satellite imagery and vegetation indices.
4. To integrate field observations, satellite-derived information and weather datasets using GIS.
5. To develop spatial pest-risk maps and a preliminary insect pest early-warning framework.

4. MATERIALS AND METHODS

4.1 Study area selection

The proposed study will be conducted in selected rice-growing areas of **[Name of Village/Block/District], Tamil Nadu, India**.

The study area will be selected based on rice cultivation, accessibility for regular field observations and the occurrence of brown planthopper.

Geographical coordinates of selected agricultural fields will be recorded using a GPS-enabled mobile device.

The study area map will be prepared using QGIS by incorporating administrative boundaries, agricultural land-use information and field sampling locations.

4.2 Selection of target insect pest

Brown planthopper (*Nilaparvata lugens* Stål) will be selected as the target insect pest because of its economic importance in rice cultivation.

The pest occurs mainly near the basal portions of rice plants, where both nymphs and adults suck plant sap.

Pest identification will be confirmed through morphological examination and standard entomological identification resources.

4.3 Field-level insect pest surveillance

Field surveys will be conducted at weekly intervals throughout the selected rice-growing season.

A stratified sampling approach will be adopted to cover different rice-growing locations.

Proposed sampling design:

- Five sampling locations will be selected across the study area.
- Five sampling points will be identified at each location.
- Ten rice hills will be examined at each sampling point.
- A total of 250 rice hills will be observed during each weekly sampling round.

The number of nymphs and adults present on each hill will be recorded.

The following observations will be collected:

1. Date of observation.
2. GPS coordinates.
3. Rice variety, if known.
4. Crop growth stage.
5. Number of brown planthopper nymphs.
6. Number of brown planthopper adults.
7. Total pest population per hill.
8. Percentage of damaged plants.

9. Presence of natural enemies.
10. General crop condition.

The same sampling procedure will be maintained throughout the study to ensure consistency.

4.4 Collection of meteorological data

Weather parameters will be collected to examine their influence on brown planthopper population fluctuations.

The following parameters will be considered:

Weather parameter	Unit
Maximum temperature	°C
Minimum temperature	°C
Morning relative humidity	%
Evening relative humidity	%
Rainfall	mm
Wind speed	m/s
Sunshine duration	Hours

Meteorological data will be obtained from available local weather stations or reliable gridded datasets.

ERA5-Land may be used as an additional source of meteorological information. It provides hourly land-surface reanalysis data at approximately 9 km native spatial resolution and includes variables such as temperature, humidity-related variables, wind and precipitation (Copernicus Climate Change Service, 2026).

Daily observations will be processed into weekly averages or totals *Corresponding to the field surveillance dates.

4.5 Satellite data collection

Sentinel-2 Level-2A surface reflectance imagery will be obtained from the Copernicus Data Space Ecosystem or Google Earth Engine.

Images *Corresponding to the crop-growing period will be selected.

The following criteria will be considered:

- Cloud-free or low-cloud satellite observations.
- Images *Corresponding to the crop-growing season.
- Consistent temporal coverage.
- Spatial coverage of the selected study area.

Cloud and cloud-shadow pixels will be removed using the Sentinel-2 Scene Classification Layer.

The satellite imagery will be processed using Google Earth Engine.

4.6 Calculation of vegetation indices

Vegetation indices will be calculated to assess crop growth and vegetation conditions.

A. Normalized Difference Vegetation Index (NDVI)

NDVI will be calculated using the near-infrared and red spectral bands.

NDVI = (NIR − Red) / (NIR + Red)

For Sentinel-2:

NDVI = (B8 − B4) / (B8 + B4)

B. Enhanced Vegetation Index (EVI)

EVI will be calculated to improve vegetation monitoring, particularly under conditions where atmospheric and canopy background effects may influence NDVI.

EVI = 2.5 × (NIR − Red) / (NIR + 6 × Red − 7.5 × Blue + 1)

For Sentinel-2:

EVI = 2.5 × (B8 − B4) / (B8 + 6B4 − 7.5B2 + 1)

C. Normalized Difference Red Edge (NDRE)

NDRE will be used to assess vegetation chlorophyll-related variation.

NDRE = (NIR − Red Edge) / (NIR + Red Edge)

For Sentinel-2:

NDRE = (B8 − B5) / (B8 + B5)

The calculated vegetation indices will be exported and analysed in GIS.

These indices will be treated as indicators of crop condition rather than direct measurements of insect population.

4.7 Integration of datasets using GIS

The collected datasets will be integrated in QGIS.

The following information will be incorporated:

1. Study area boundary.
2. Agricultural field locations.
3. GPS-based pest population observations.
4. Meteorological parameters.
5. Sentinel-2 vegetation indices.
6. Crop growth-stage information.

All spatial datasets will be checked for coordinate reference system consistency.

Pest population observations will be represented as georeferenced point data.

Spatial interpolation techniques, such as Inverse Distance Weighting (IDW), may be used to visualise pest distribution where sampling density and spatial structure justify their use.

The resulting maps will help identify areas with comparatively higher and lower pest populations.

4.8 Statistical analysis

Statistical analysis will be carried out to examine relationships between insect pest population, weather conditions and vegetation indices.

The following statistical methods will be considered:

A. Descriptive statistics

Mean, standard deviation, minimum and maximum values will be calculated for pest population and weather parameters.

B. Correlation analysis

Pearson or Spearman correlation analysis will be performed depending on the data distribution to examine relationships between pest population and environmental parameters.

C. Multiple regression analysis

A multiple regression model may be developed to examine the combined influence of environmental variables on pest population.

A general model can be expressed as:

$$P = \beta_0 + \beta_1 T + \beta_2 RH + \beta_3 RF + \beta_4 NDVI + \beta_5 NDRE + \varepsilon$$

Where:

- P = Brown planthopper population.
- T = Temperature.
- RH = Relative humidity.
- RF = Rainfall.
- NDVI = Normalized Difference Vegetation Index.
- NDRE = Normalized Difference Red Edge.
- β_0 = Intercept.
- β_1–β_5 = Regression coefficients.
- ε = Error term.

Where pest counts show overdispersion, a negative binomial regression model may be more appropriate than ordinary linear regression.

Weather variables from previous weeks may also be included to account for delayed effects on pest population development.

4.9 Development of the pest-risk prediction model

The collected datasets will be used to develop a preliminary pest-risk prediction model.

The model will integrate:

- Current and previous weather conditions.
- Vegetation index values.
- Crop growth stage.
- Previous pest population observations.
- Spatial distribution of pest incidence.

A statistical or machine-learning model may be developed depending on the quantity and quality of available observations.

The pest-risk classification will be divided into three categories:

Risk category	Interpretation
Low risk	Low pest population and no immediate indication of increasing infestation
Moderate risk	Increasing pest population or environmental conditions associated with increased pest activity
High risk	Pest population approaching or exceeding the locally recommended economic threshold level

For rice, the National Institute of Plant Health Management's rice IPM package lists brown planthopper/white-backed planthopper thresholds of 10–15 hoppers per hill during early to late tillering and 15–20 hoppers per hill from panicle initiation to booting. These values should be checked against the applicable crop-stage and regional recommendations before operational use. The final risk maps will be prepared in QGIS.

4.10 Validation of the prediction model

The prediction model will be evaluated using independent field observations that were not used during model training.

Where sufficient observations are available, the dataset will be divided into training and testing subsets, preferably with temporal or spatial separation to avoid data leakage.

The following evaluation measures may be used:

- Root Mean Square Error (RMSE).
- Mean Absolute Error (MAE).
- Coefficient of determination (R^2).

- Precision.
- Recall.
- F1-score.
- Area Under the Receiver Operating Characteristic Curve (AUC), where appropriate.

The model's ability to identify high-risk locations before pest populations reach economically important levels will be assessed.

4.11 Development of the early-warning framework

The final stage will involve integrating the processed information into a GIS-based pest surveillance and warning framework.

The system will use updated field observations, weather information and satellite-derived crop conditions to generate pest-risk assessments.

The proposed warning framework will include:

1. Collection of weekly field pest observations.
2. Updating of meteorological datasets.
3. Processing of satellite imagery.
4. Calculation of vegetation indices.
5. Integration of datasets in GIS.
6. Generation of pest-risk maps.
7. Identification of locations requiring additional field surveillance.
8. Communication of warnings and management recommendations.

The system will provide a basis for developing a future operational pest early-warning platform.

5. PROPOSED DATA ANALYSIS AND OUTPUTS

The following outputs are expected from the proposed study.

5.1 Spatial distribution of brown planthopper

GPS-based field observations will be used to prepare pest distribution maps showing the spatial variation of brown planthopper populations across the selected study area.

5.2 Relationship between weather and pest population

Statistical analysis will help identify meteorological variables associated with fluctuations in brown planthopper population.

5.3 Crop vegetation condition maps

NDVI, EVI and NDRE maps will be prepared to represent spatial variation in rice crop vegetation conditions.

5.4 GIS-based pest-risk zonation

Agricultural areas will be classified into low-, moderate- and high-risk zones based on the validated pest-risk model.

5.5 Early-warning framework

A preliminary GIS-based warning framework will be developed to support regular monitoring and timely identification of potential pest outbreak locations.

6. EXPECTED RESULTS AND DISCUSSION

The proposed study is expected to demonstrate the usefulness of integrating field-level entomological observations, meteorological data and satellite-derived vegetation information for pest-risk assessment.

The weekly field observations are expected to provide information about the temporal and spatial variation of brown planthopper populations.

Weather data analysis may reveal associations between temperature, relative humidity, rainfall and pest population fluctuations. However, the strength and direction of these relationships will need to be established using actual field observations.

Sentinel-2-derived vegetation indices are expected to provide information about the spatial variation in rice crop conditions. Changes in vegetation indices may help identify areas requiring closer field investigation, although such changes cannot be attributed to brown planthopper infestation without field verification.

The integration of these datasets in GIS is expected to provide a spatial representation of pest distribution and environmental conditions.

The prediction model may help identify locations requiring intensified pest surveillance. Its usefulness will depend on the quality of field observations, temporal coverage, model validation and the availability of reliable weather information.

The proposed framework may also be extended to other economically important agricultural pests by modifying the sampling methods, pest-specific biological parameters and risk thresholds.

7. LIMITATIONS OF THE STUDY

The proposed approach may have certain limitations:

1. Cloud cover may affect the availability of usable Sentinel-2 images.
2. Satellite-derived vegetation indices cannot directly identify most insect pest species.
3. Pest population observations may vary due to field management practices and sampling conditions.
4. Gridded meteorological datasets may not represent all local microclimatic variations.
5. Different rice varieties and crop growth stages may respond differently to pest infestation.
6. A reliable prediction model requires sufficient field observations across different locations and crop seasons.
7. Pest immigration, natural enemies and insecticide applications may influence population dynamics independently of the measured environmental variables.

These limitations will be considered during model development and interpretation.

8. CONCLUSION

The proposed study presents an integrated approach for developing an insect pest early-warning system using remote sensing, weather data and Geographic Information Systems.

By combining weekly field-level brown planthopper surveillance with Sentinel-2-derived vegetation indices and meteorological parameters, the study aims to improve the understanding of pest population dynamics and their spatial distribution in rice ecosystems.

The integration of these datasets using Google Earth Engine and QGIS will provide a framework for preparing pest distribution maps, analysing environmental relationships and identifying potential pest-risk zones.

The proposed model is intended to support preventive surveillance and timely integrated pest management decisions rather than replace conventional field scouting.

Overall, the research may contribute to the development of geospatially enabled digital pest surveillance systems and provide a foundation for future precision agriculture and smart pest management applications.

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A SCIENTOMETRIC ANALYSIS OF CRISPR RESEARCH IN AGRICULTURAL AND BIOLOGICAL SCIENCES: KNOWLEDGE STRUCTURE, TRENDS AND VISUALIZATION (2016–2025)

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Abstract

This study presents a bibliometric analysis of CRISPR research in the fields of agricultural and biological sciences during the period **2016–2025**. The study uses bibliographic data retrieved from the **Scopus database** using the search terms "CRISPR" and "Clustered Regularly Interspaced Short Palindromic Repeats," with the subject area restricted to Agricultural and Biological Sciences. The analysis examines publication growth, open-access patterns, document types, leading authors, source titles, keywords, institutions, funding agencies, and countries. The results indicate a substantial increase in CRISPR-related research output, with publications rising from **285 in 2016 to 3,145 in 2025** in the displayed dataset. Agricultural and Biological Sciences was the leading subject area, while genetics, CRISPR-Cas systems, gene editing, metabolism, and plant-related research were prominent themes. China, the United States, and India were among the leading contributing countries. The findings demonstrate the rapid expansion and increasing interdisciplinary nature of CRISPR research and highlight its importance for crop improvement, plant biotechnology, genetic engineering, and agricultural innovation.

Keywords: CRISPR; CRISPR-Cas; Gene Editing; Bibliometric Analysis; Agricultural Sciences; Biological Sciences; Genome Editing; Science Mapping.

1. Introduction

Clustered Regularly Interspaced Short Palindromic Repeats (**CRISPR**) and CRISPR-associated proteins (**Cas**) have become important tools in modern genetic research and biotechnology. The development of CRISPR-based genome-editing technologies has created new opportunities for modifying genes with increasing precision and has stimulated research across agriculture, plant biology, genetics, microbiology, animal sciences, and related disciplines.

In agricultural research, CRISPR technologies have attracted considerable attention because of their potential applications in **crop improvement, disease resistance, stress tolerance, yield improvement, nutritional enhancement, plant breeding, and functional genomics**. The growing research output has also resulted in an increasingly interdisciplinary scientific literature.

Bibliometric analysis provides a systematic approach for examining the development and structure of a research field. It enables researchers to identify publication trends, influential authors, major journals, geographical contributions, institutional participation, research themes, and emerging areas of investigation. Science mapping and visualization further help to understand relationships among keywords, research topics, authors, and institutions.

The present study therefore examines the development of CRISPR research in agricultural and biological sciences over the **2016–2025** period. The Scopus search used in the dataset combines CRISPR-related terms with a restriction to the Agricultural and Biological Sciences subject area.

The major objectives of the study are:

1. To examine the annual growth of CRISPR research from 2016 to 2025.
2. To identify major authors and publication sources.
3. To analyze the major subject areas and research keywords.
4. To identify leading countries and institutions.
5. To examine open-access and document-type patterns.
6. To identify major research trends and themes in agricultural and biological CRISPR research.

2. Methodology

2.1 Data Source

The bibliographic data for this study were obtained from the **Scopus database**. Scopus was selected because it provides comprehensive bibliographic information relating to authors, publications, affiliations, countries, source titles, keywords, subject areas, and funding organizations.

2.2 Search Strategy

The Scopus search strategy used in the dataset was:

TITLE-ABS-KEY("CRISPR") OR TITLE-ABS-KEY("Clustered Regularly Interspaced Short Palindromic Repeats")

The search was restricted to the **Agricultural and Biological Sciences (AGRI)** subject area and publications from **2016 to 2025**.

2.3 Study Period

The analysis covers **ten years, from 2016 through 2025**. The dataset shows a continuous increase in annual publication output, from **285 publications in 2016** to **3,145 publications in 2025**.

2.4 Bibliometric Indicators

The following indicators were examined:

- Annual publication output
- Open-access publication types
- Document types
- Subject areas
- Authors
- Source titles/journals
- Keywords
- Affiliations and institutions
- Funding sponsors
- Countries of publication

The dataset particularly highlights **Genetics, CRISPR-Cas Systems, Gene Editing, Metabolism, Plant Biology, Plant Breeding, Crop Improvement, and Genome Editing** as important research-related terms.

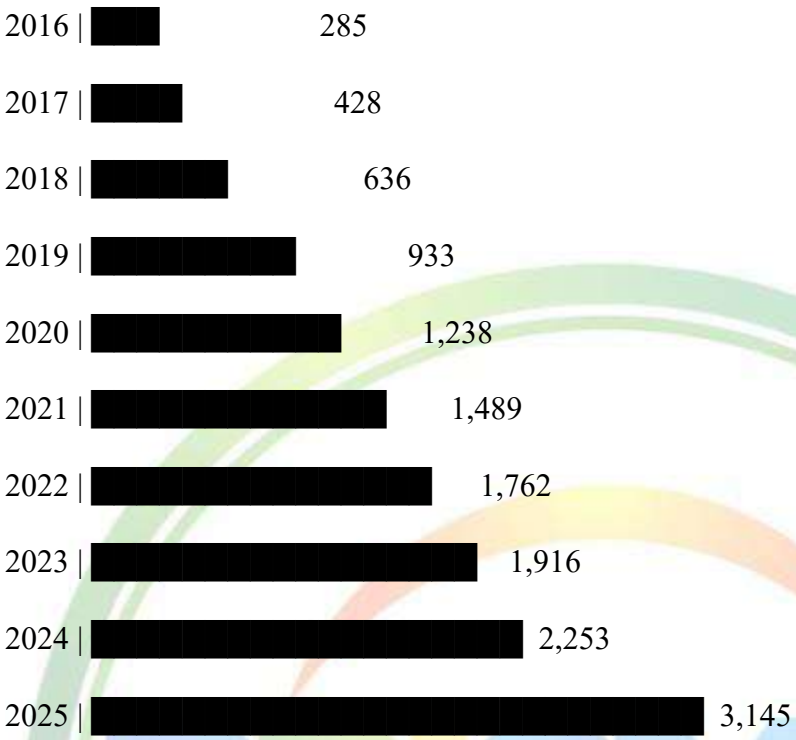
2.5 Data Analysis

The retrieved Scopus data were organized and analyzed using bibliometric indicators and graphical presentation. Publication trends were examined year-wise, while author, country, source-title, keyword, institution, and funding patterns were used to identify the structure and development of CRISPR research.

Table 1. Annual Publication Growth of CRISPR Research, 2016–2025

Year	Publications
2016	285
2017	428
2018	636
2019	933
2020	1,238
2021	1,489
2022	1,762
2023	1,916
2024	2,253
2025	3,145

Figure 1. Annual Publication Growth



Annual Publication Growth of CRISPR Research

Table 1 and Figure 1 present the annual publication growth of CRISPR research in agricultural and biological sciences from 2016 to 2025. The number of publications increased consistently throughout the study period. In 2016, only **285 publications** were recorded, which increased to **428 in 2017** and **636 in 2018**. The publication output continued to rise to **933 in 2019** and crossed 1,000 publications in 2020, reaching **1,238 publications**.

The growth continued during 2021–2024, with **1,489, 1,762, 1,916, and 2,253 publications**, respectively. The highest publication output was observed in **2025, with 3,145 publications**. Thus, the data demonstrate a strong and sustained expansion of CRISPR research during the ten-year period.

The increase from **285 publications in 2016 to 3,145 in 2025** represents more than a tenfold increase in publication output. This trend indicates the growing research interest in CRISPR technologies and their applications within agricultural and biological sciences.

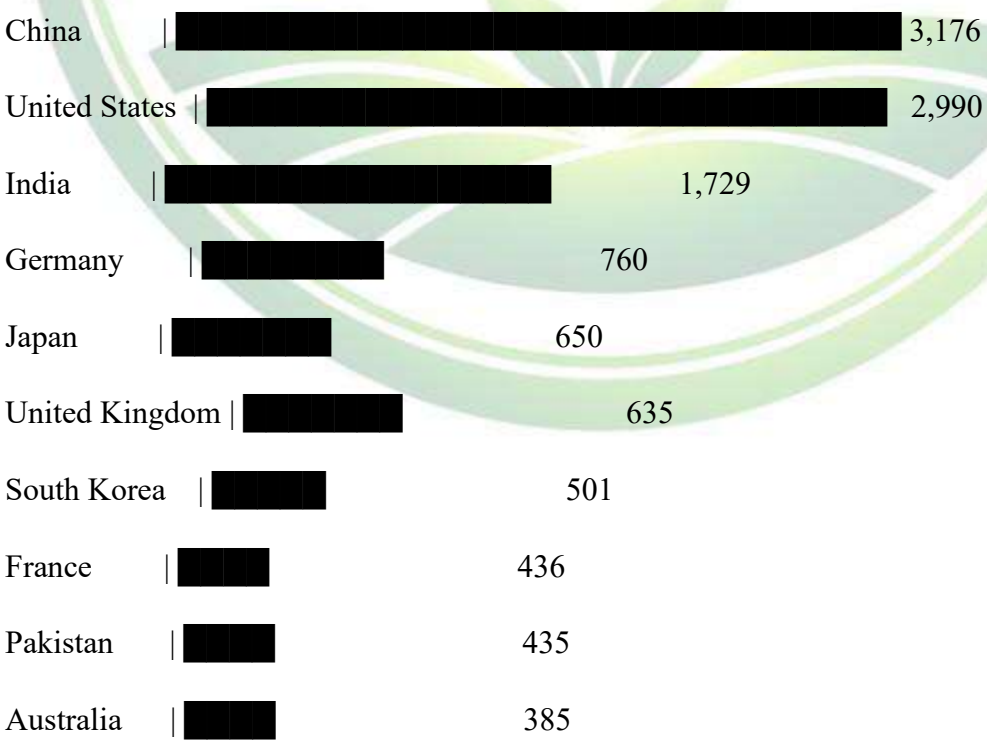
Interpretation: The continuous upward trend suggests that CRISPR has developed from an emerging research topic into a major research area, particularly in areas associated with genome editing, genetics, plant biotechnology and agricultural applications

The publication output increased continuously from 285 records in 2016 to 3,145 records in 2025.

Table 2. Leading Countries in CRISPR Research

Rank	Country	Publications
1	China	3,176
2	United States	2,990
3	India	1,729
4	Germany	760
5	Japan	650
6	United Kingdom	635
7	South Korea	501
8	France	436
9	Pakistan	435
10	Australia	385

Figure 2. Top 10 Countries



Country-wise Distribution of CRISPR Research

Table 2 and Figure 2 show the ten leading countries contributing to CRISPR research. **China ranked first with 3,176 publications**, followed by the **United States with 2,990 publications**. **India ranked third with 1,729 publications**, demonstrating a substantial contribution to the research field.

Germany occupied fourth position with **760 publications**, followed by Japan (**650**) and the United Kingdom (**635**). South Korea, France, Pakistan and Australia recorded **501, 436, 435 and 385 publications**, respectively.

The difference between the leading three countries and the remaining countries is considerable. China and the United States together account for a particularly large share of the publications shown in the table, while India's third-place position indicates its important contribution to CRISPR-related research.

Interpretation: The country distribution demonstrates that CRISPR research is internationally distributed but concentrated particularly in **China, the United States and India**. The strong representation of India is especially relevant to agricultural and biological research because of the importance of crop improvement and biotechnology research in the country.

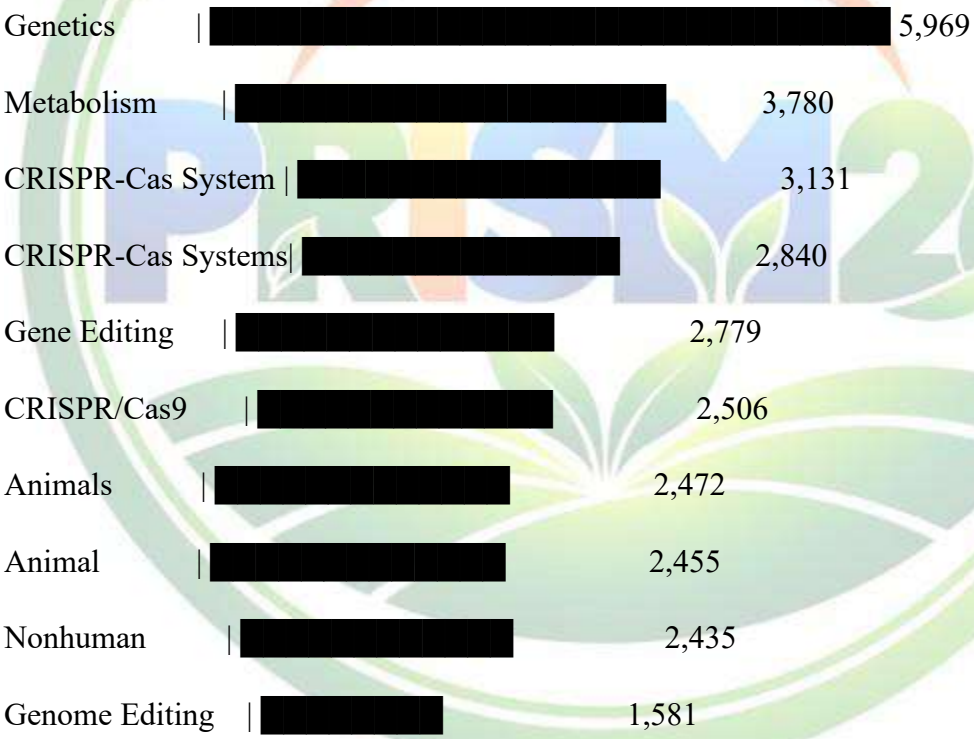
China, the United States and India are the three largest country contributors in the displayed data.

Table 3. Major Research Keywords

Rank	Keyword	Publications
1	Genetics	5,969
2	Metabolism	3,780
3	CRISPR-Cas System	3,131
4	CRISPR-Cas Systems	2,840

Rank	Keyword	Publications
5	Gene Editing	2,779
6	CRISPR/Cas9	2,506
7	Animals	2,472
8	Animal	2,455
9	Nonhuman	2,435
10	Genome Editing	1,581

Figure 3. Major Research Keywords



Major Research Keywords

Table 3 and Figure 3 identify the major keywords associated with CRISPR research. **Genetics** was the most frequently occurring keyword, with **5,969 publications**, followed by **Metabolism (3,780)**. The terms **CRISPR-Cas System (3,131)** and **CRISPR-Cas Systems (2,840)** were also highly represented.

Gene Editing appeared in **2,779 publications**, while **CRISPR/Cas9** occurred in **2,506 publications**. Other frequently occurring terms included **Animals (2,472), Animal (2,455), Nonhuman (2,435)** and **Genome Editing (1,581)**.

The keyword distribution indicates that CRISPR research is strongly connected with genetic research and genome manipulation. The frequent appearance of CRISPR-Cas-related terms demonstrates the central importance of CRISPR-associated systems in the research literature.

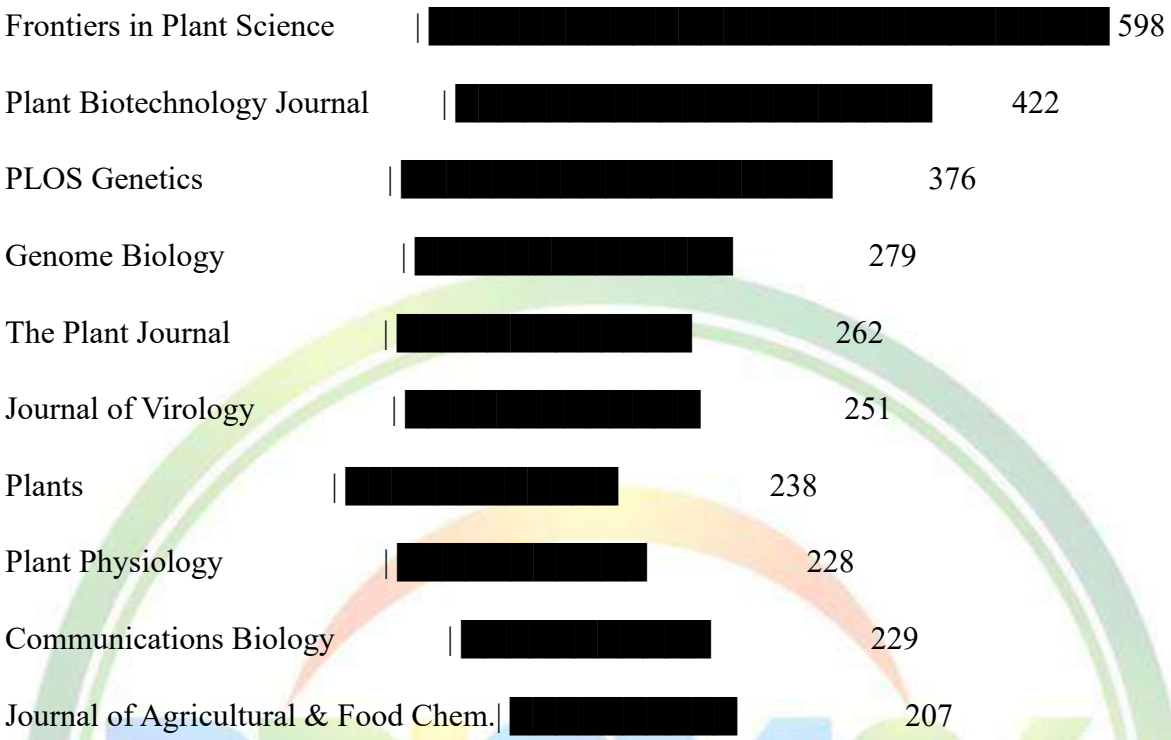
Interpretation: The keyword results reveal three broad research directions: **genetics and biological processes, CRISPR/Cas technologies, and gene/genome editing applications**. The presence of animal-related terms also indicates that CRISPR research extends beyond plant science into broader biological applications.

The keyword profile indicates strong concentration around genetics, CRISPR-Cas systems and gene-editing research.

Table 4. Leading Source Titles/Journals

Rank	Source Title	Publications
1	*Frontiers in Plant Science*	598
2	*Plant Biotechnology Journal*	422
3	*PLOS Genetics*	376
4	*Genome Biology*	279
5	*The Plant Journal*	262
6	*Journal of Virology*	251
7	*Plant Physiology*	228
8	*Communications Biology*	229
9	*Plants*	238
10	*Journal of Agricultural and Food Chemistry*	207

Figure 4. Leading Journals



Leading Source Titles/Journals

Table 4 and Figure 4 present the leading source titles publishing CRISPR-related research. *Frontiers in Plant Science* ranked first with **598 publications**, followed by *Plant Biotechnology Journal* with **422 publications** and *PLOS Genetics* with **376 publications**.

Other important source titles included *Genome Biology* (**279**), *The Plant Journal* (**262**), *Journal of Virology* (**251**), *Plants* (**238**), *Communications Biology* (**229**), *Plant Physiology* (**228**) and *Journal of Agricultural and Food Chemistry* (**207**).

The prominence of plant-science and plant-biotechnology journals is particularly significant because the study focuses on agricultural and biological sciences. At the same time, the presence of genetics, genomics and virology journals demonstrates the interdisciplinary character of CRISPR research.

Interpretation: The source-title analysis indicates that CRISPR research is disseminated through a combination of **plant science, biotechnology, genetics, genomics and broader biological science journals**. *Frontiers in Plant Science* is the most prominent source among the journals listed in the dataset.

Frontiers in Plant Science is the highest-ranked source title in the displayed dataset.

Table 5. Leading Authors

Rank	Author	Publications
1	Qi, Y.	68
2	Zhu, J.K.	49
3	Puchta, H.	48
4	Huang, Y.	46
5	Ahmad, A.	45
6	Zhang, Y.	45
7	Yang, B.	35
8	Le Bras, A.	34
9	Zhang, X.	33
10	Gao, C.	32

Figure 5. Top Authors



Leading Authors in CRISPR Research

Table 5 and Figure 5 show the ten leading authors according to the number of publications. **Qi, Y.** ranked first with **68 publications**, followed by **Zhu, J.K. (49)** and **Puchta, H. (48)**. Huang, Y. contributed **46 publications**, while Ahmad, A. and Zhang, Y. each recorded **45 publications**.

Yang, B. had **35 publications**, followed by Le Bras, A. (**34**), Zhang, X. (**33**) and Gao, C. (**32**).

The relatively close publication counts among several leading authors indicate the participation of a group of highly productive researchers rather than a single dominant author. These researchers contribute to the development of CRISPR-related knowledge across genetics, genome editing and biotechnology.

Interpretation: The author analysis helps identify the most productive contributors and provides an indication of the concentration of research expertise within the CRISPR research community.

Overall Findings

The five tables and *Corresponding figures collectively demonstrate the development and structure of CRISPR research between 2016 and 2025.

The major findings are:

1. **Rapid publication growth:** CRISPR publications increased from **285 in 2016 to 3,145 in 2025**.
2. **Strong international contribution:** China, the United States and India were the three leading countries in the displayed data.
3. **Dominant research themes:** Genetics, metabolism, CRISPR-Cas systems, gene editing and genome editing were major research terms.
4. **Important publication venues:** *Frontiers in Plant Science*, *Plant Biotechnology Journal* and *PLOS Genetics* were among the leading source titles.
5. **Productive researchers:** Qi, Y., Zhu, J.K. and Puchta, H. were the three most productive authors in the displayed author data.

6. **Interdisciplinary nature:** The presence of agricultural, plant, genetics, genomics, animal and virology-related terms and journals indicates that CRISPR research spans multiple areas of biological science.

Overall conclusion from the tables

The bibliometric results show that **CRISPR research has experienced substantial and continuous growth during 2016–2025**. The increasing publication volume, broad international participation, diverse research keywords and presence across multiple scientific journals demonstrate that CRISPR has become an important and interdisciplinary research domain in agricultural and biological sciences.

Conclusion

The bibliometric analysis demonstrates the **rapid growth of CRISPR research in agricultural and biological sciences during 2016–2025**. Publication output increased substantially during the study period, reaching **3,145 publications in 2025** compared with 285 in 2016.

The results indicate that CRISPR research is strongly associated with **genetics, gene editing, CRISPR-Cas systems, metabolism, plant genetics, crop improvement, genome editing, and disease resistance**. The Agricultural and Biological Sciences category was the largest subject area represented in the dataset.

China, the United States, and India were among the leading countries contributing to the research output. The dataset also shows strong participation from agricultural and research institutions, including Chinese Academy of Agricultural Sciences, Chinese Academy of Sciences, Huazhong Agricultural University, China Agricultural University, ICAR, ICAR–Indian Agricultural Research Institute, and Tamil Nadu Agricultural University.

Overall, the findings suggest that CRISPR has developed into an important research domain with significant implications for **plant biotechnology, crop improvement, agricultural productivity, genetic engineering, and sustainable agriculture**. Future research may increasingly focus on precision breeding, climate-resilient crops, disease resistance, nutritional improvement, and responsible application of genome-editing technologies.

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INNOVATIONS IN AGRICULTURAL AND BIOLOGICAL SCIENCES FOR SUSTAINABLE CROP PROTECTION

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Abstract

Agriculture faces increasing challenges from insect pests, plant pathogens and weeds, which significantly affect crop productivity, food security and environmental sustainability. Conventional crop protection practices largely depend on synthetic pesticides, resulting in concerns related to pesticide resistance, environmental pollution, biodiversity loss and harmful effects on non-target organisms. In this context, innovations in agricultural and biological sciences offer promising approaches for developing sustainable and environmentally friendly crop protection strategies.

The present review highlights recent advancements in sustainable crop protection, with particular emphasis on biological control agents, microbial biopesticides, integrated pest management (IPM), plant microbiome technology and precision agriculture. Beneficial microorganisms such as *Bacillus*, *Pseudomonas* and *Trichoderma* play an important role in suppressing plant pathogens, enhancing plant growth and improving crop resilience. The utilization of natural enemies, botanicals and microbial-based formulations provides alternatives to conventional chemical pesticides. Furthermore, advances in molecular biotechnology, including RNA interference (RNAi) and CRISPR-based approaches, offer new opportunities for targeted pest and disease management. The integration of artificial intelligence, remote sensing, drones and smart sensors enables early detection of pest infestations and precise application of crop protection measures, thereby reducing unnecessary pesticide use. These innovations collectively contribute to improved crop health, reduced environmental risks, conservation of beneficial organisms and sustainable agricultural production. However, challenges related to field-level effectiveness, formulation stability, economic feasibility, regulatory approval and farmer adoption need further attention. Integrating biological, ecological and technological approaches through sustainable crop protection strategies can play a significant role in achieving environmentally responsible and resilient agricultural systems.

Keywords: Sustainable crop protection, Biological control, Biopesticides, Integrated Pest Management, Plant microbiome, Precision agriculture, Artificial intelligence, Agricultural biotechnology.

INTEGRATING BIOTECHNOLOGICAL INNOVATIONS AND BIOLOGICAL CONTROL FOR SUSTAINABLE CROP PROTECTION

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Abstract

Agricultural productivity is increasingly challenged by insect pests, plant diseases, pesticide resistance and environmental degradation, creating a need for innovative and sustainable crop protection strategies. Advances in agricultural and biological sciences offer promising opportunities to reduce crop losses while maintaining ecological balance and protecting beneficial organisms. Integrated pest management (IPM), botanical pesticides, microbial biocontrol agents, semiochemicals and precision-based pest monitoring are emerging approaches that can improve the effectiveness and sustainability of crop protection. Botanical formulations derived from plant extracts and essential oils have attracted attention as potential alternatives to conventional pesticides because of their diverse bioactive compounds. Similarly, entomopathogenic microorganisms and naturally occurring predators and parasitoids can contribute to effective pest suppression while supporting ecosystem services. Emerging technologies, including nanoformulations and improved delivery systems, may further enhance the stability, efficacy and targeted application of biopesticides. Integrating these innovations with biological control, crop monitoring and appropriate agronomic practices can help reduce unnecessary pesticide use, delay the development of insecticide resistance and minimize adverse effects on non-target organisms. However, their successful application requires systematic laboratory evaluation, field validation, ecological safety assessment and economic analysis under different cropping conditions. Strengthening collaboration among agricultural researchers, biological scientists and farmers is essential for translating scientific innovations into practical crop protection solutions. Overall, integrating modern agricultural technologies with biologically based pest management can contribute to sustainable crop production, improved environmental health and long-term agricultural resilience.

Keywords: Biotechnological innovations, biological control, integrated pest management, botanical pesticides, biopesticides, sustainable agriculture.

CLIMATE RESILIENT INTEGRATED PEST MANAGEMENT: INNOVATIONS, ECOLOGICAL APPROACHES AND FUTURE STRATEGIES FOR SUSTAINABLE CROP PROTECTION

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Abstract

Climate change is creating new challenges for agricultural production by altering the distribution, abundance, development and seasonal activity of insect pests. Rising temperatures, changes in rainfall, elevated atmospheric carbon dioxide and more frequent extreme weather events can affect pest host plant relationships, natural enemy populations and the performance of existing management practices. These changes may favour additional pest generations, permit range expansion, disturb the synchrony between pests and their natural enemies, and increase the risk of outbreaks in some production systems. Calendar-based pesticide use alone is unlikely to provide a reliable response to such variable conditions. Climate-resilient integrated pest management (IPM) instead combines preventive crop practices, host plant resistance, biological control, ecological engineering, surveillance, forecasting and carefully selected chemical interventions. Weather information, digital monitoring and decision support can help align management actions with pest development and crop vulnerability. This chapter reviews climate-related changes in agricultural pest dynamics and discusses strategies for strengthening IPM, with emphasis on their relevance to Indian agriculture. It also considers research gaps, technology access and the importance of farmer-centred adaptation. An adaptive framework linking climate intelligence, field surveillance, risk assessment and integrated interventions is proposed as a practical foundation for sustainable crop protection.

Keywords: Climate change; integrated pest management; climate resilience; biological control; ecological engineering; insect pests; precision agriculture; sustainable crop protection.

1. Introduction

Crop production is closely linked to climatic conditions. Temperature, rainfall, humidity and atmospheric composition influence crop growth as well as the insects and other organisms associated with crops. Climate change is therefore not only an environmental concern; it is also

a plant-health and food-security challenge. Because insects are ectothermic, their development, survival and reproduction are particularly responsive to environmental conditions.

Warmer conditions may speed up insect development and allow some species to complete more generations in a season. Shifts in rainfall and humidity can change pest survival, host-plant quality and natural-enemy activity. Climatic changes may also make previously unsuitable areas more favourable for certain pests, including invasive species. The direction and magnitude of these responses differ among species and locations: warming can benefit a pest within its thermal range but suppress it when temperatures exceed its tolerance.

Integrated Pest Management (IPM) combines compatible biological, cultural, physical, mechanical and chemical approaches to keep pest populations below economically damaging levels while limiting risks to people and the environment. Under climate change, IPM needs to be more adaptive and anticipatory. Climate-resilient IPM brings weather information, ecological processes and pest surveillance into management decisions, enabling growers to respond to changing risks rather than relying solely on fixed calendars. This chapter reviews key climate-related changes in pest systems and practical approaches for strengthening resilient crop protection, with particular relevance to Indian agriculture.

2. Climate Change and Agricultural Insect Pest Dynamics

2.1. Temperature and insect development. Temperature is a major driver of insect development. Within a species' suitable thermal range, moderate warming can shorten the time required to complete immature stages, alter adult emergence and increase the number of generations possible in a growing season. These changes can affect pests such as aphids, whiteflies, thrips, leafhoppers and several lepidopteran species. Responses are not uniformly positive: excessive heat can reduce survival, fecundity and population growth, and can shift the balance between pests and their natural enemies.

2.2. Changes in geographical distribution. Changes in average temperature and seasonal extremes can alter the climatic suitability of regions. Some pests may move toward higher elevations or latitudes, while others may establish in areas where winter or seasonal conditions previously restricted them. Trade and movement of plant material can interact with these climatic opportunities, making surveillance and phytosanitary safeguards increasingly important.

2.3. Rainfall and humidity. Rain can dislodge exposed insects or reduce survival, while moderate moisture may support host-plant growth and create favourable conditions for some pest species. Drought may change plant water status, nutritional composition and defensive chemistry. Some herbivores perform better on stressed plants, whereas others decline when host resources become limited. Local conditions and species biology determine the outcome.

2.4. Extreme events. Heatwaves, droughts, floods and irregular monsoon patterns may cause direct mortality, disrupt migration and reproduction, change crop phenology, or interfere with field operations. Extreme events can also reduce the availability or activity of natural enemies and delay timely interventions. Pest management plans should therefore account for variability and extremes, not only long-term mean temperatures.

3. Climate Change and Plant–Pest–Natural Enemy Interactions

3.1. Host-plant susceptibility. Elevated carbon dioxide and temperature can influence plant growth, carbon-to-nitrogen balance, tissue quality and defensive compounds. These changes may affect herbivore feeding and development, but effects vary with crop species, insect species and growing conditions. Drought and heat stress can further alter plant chemistry and susceptibility, with consequences for resistance-based management.

3.2. Natural enemies. Predators, parasitoids and entomopathogens provide essential pest-regulation services. Their development, survival, searching behaviour and reproductive performance are also climate-sensitive. For instance, the performance of parasitoids such as Trichogramma spp. or *Acerophagus papayae*, and predators such as ladybird beetles and lacewings, can vary with temperature and humidity. The climate response of a control agent should be considered alongside that of its target pest.

3.3. Trophic synchrony. A pest may respond to warming more rapidly than its parasitoid or predator, potentially weakening biological control during a vulnerable crop stage. Climate-related changes in plant volatile emissions may also influence host or prey location. These interactions underline the need to study the crop, pest and natural enemy as a connected system rather than as separate components.

4. Principles of Climate-Resilient IPM

Climate-resilient IPM is an adaptive extension of conventional IPM. It seeks to prevent pest establishment, maintain populations below economic injury levels, conserve ecological

regulation, reduce unnecessary pesticide use and sustain production under climatic variability. Its central principles are prevention, regular monitoring, locally relevant thresholds, integration of compatible tactics, evaluation of outcomes and adjustment as conditions change.

Climate-resilient IPM is not a single technology or a fixed package. It is a decision framework in which practices are selected according to crop, pest, location, season, weather and the resources available to growers.

5. Cultural and Preventive Management

5.1. Crop diversification and rotation. Rotation with non-host crops can interrupt pest survival, particularly for crop-specific pests and some soil-associated species. Intercropping and mixed cropping may interfere with host location and provide resources for beneficial organisms. These practices need to be planned carefully because some companion plants can also serve as pest or pathogen reservoirs.

5.2. Sowing-date adjustment. Altering planting dates can help crops avoid periods when pest pressure or climatic stress is expected to be high. Decisions should draw on local pest forecasts and crop phenology rather than generalized calendar advice. Crop-market requirements, water availability and regional agronomy must also be considered.

5.3. Resistant and climate-adapted cultivars. Host-plant resistance can reduce pest establishment, feeding or reproduction without repeated pesticide applications. Breeding priorities should combine pest resistance with tolerance to heat, drought, salinity and other stresses. Resistance and biological control can be complementary when compatible varieties and natural enemies are selected.

5.4. Sanitation and habitat management. Removing infested residues, volunteer plants and alternative hosts can reduce pest carry-over between seasons. At the same time, suitable refuge and flowering habitats can support beneficial organisms. The distinction between helpful vegetation and pest reservoirs should be made using local evidence.

6. Biological Control for Climate-Resilient Pest Management

6.1. Conservation biological control. Conservation biological control protects and enhances naturally occurring enemies. Practices include retaining appropriate refuge vegetation, providing floral resources, reducing unnecessary broad-spectrum pesticide use and maintaining

habitat connectivity. These measures can improve ecological regulation, although their effectiveness depends on the local landscape and pest complex.

6.2. Augmentative biological control. Periodic releases of mass-reared agents can supplement natural enemy populations. Examples include *Trichogramma* spp. against eggs of selected lepidopteran pests; *Chrysoperla* spp. against aphids and other soft-bodied insects; *Encarsia* and *Eretmocerus* spp. against whiteflies; and *Acerophagus papayae* against papaya mealybug, *Paracoccus marginatus*. Entomopathogenic fungi such as Beauveria bassiana and Metarhizium anisopliae may also be useful against selected pests.

6.3. Climate-adapted agents. Selection and deployment should consider thermal tolerance, humidity requirements, host availability and synchronization with the target. Research needs include evaluating survival and reproduction across temperature ranges, host-searching under heat stress, pesticide compatibility and field performance under local climatic conditions. Use of locally adapted agents, where scientifically validated and permitted, may improve reliability.

7. Ecological Engineering and Landscape-Level Management

Ecological engineering deliberately modifies agricultural habitats to encourage beneficial ecological interactions and ecosystem services. Flowering strips, border crops, hedgerows, intercrops and carefully selected non-crop vegetation can provide nectar, pollen, alternative prey, shelter and overwintering sites for natural enemies.

Push–pull approaches combine deterrent or repellent plants within the main crop with attractive trap plants near the crop. They can redirect pest movement, but their success depends on pest behaviour, plant compatibility, landscape design and climatic suitability. Agroforestry and diversified landscapes may moderate microclimates and support beneficial organisms; however, some non-crop plants can also harbour pests. Ecological engineering therefore requires locally appropriate species selection and ongoing surveillance.

8. Precision Agriculture and Digital Technologies

8.1. Remote sensing and GIS. Satellite imagery, unmanned aerial vehicles and geographic information systems can help assess vegetation condition, crop stress and spatial patterns of risk. These tools generally detect plant or canopy responses rather than identify a causal insect directly, so field scouting and validation remain essential.

8.2. Artificial intelligence and machine learning. Image-based systems can assist insect identification, crop-stress classification and pest-risk prediction. Models may combine weather, crop stage, trap counts and field observations. Their reliability depends on representative training data and validation; models trained in one region may not transfer accurately to another.

8.3. IoT and automated monitoring. Connected traps and environmental sensors can provide frequent observations of pest activity and weather. Camera-equipped traps may reduce manual counting and support early warnings, provided that image quality, connectivity, maintenance and local calibration are addressed.

8.4. Weather-based forecasting. Temperature, humidity and rainfall data can be used to estimate pest development and outbreak risk. Degree-day models can support predictions of developmental stages and help time scouting, biological-control releases or pesticide applications. Forecasts should be validated in the field and updated as crop varieties, pest populations and climatic patterns change.

9. Climate-Resilient Chemical Pest Management

Chemical pesticides remain an option when pest populations exceed economic thresholds and other tactics are insufficient. Their performance can be influenced by temperature, humidity, rainfall, plant growth and degradation. Application planning should consider weather conditions, pest stage, crop stage, wind and the product label. Rain soon after application may reduce persistence for some formulations, while wind can increase drift.

Resistance management is also essential. Repeated use of insecticides with the same mode of action can select for resistance, and changing pest generation times may affect selection pressure. Recommended practices include rotating modes of action, avoiding unnecessary applications, using registered products at label rates, monitoring susceptibility and integrating non-chemical tactics. Label directions, pre-harvest intervals and local regulations must always be followed.

10. Relevance to Indian Agriculture

India’s varied agroclimatic regions and cropping systems require location-specific climate-resilient IPM approaches.

10.1. Rice. Brown planthopper (*Nilaparvata lugens*), white-backed planthopper (*Sogatella furcifera*), yellow stem borer (*Scirpophaga incertulas*) and leaf folder (*Cnaphalocrocis medinalis*) are important pests. Relevant measures include weather-informed surveillance, resistant varieties, conservation of spiders and other natural enemies, appropriate water and nutrient management, and threshold-based pesticide use.

10.2. Cotton. Bollworms, whiteflies, aphids, thrips and mealybugs can be affected by climatic conditions. IPM can combine resistant cultivars, sanitation, refuge management where applicable, biological control, pheromone monitoring and selective insecticides. Balanced nitrogen use and avoiding unnecessary sprays can help limit conditions favourable to certain sucking pests and preserve natural enemies.

10.3. Horticultural crops. Horticultural systems face complex pest assemblages, including papaya mealybug (*Paracoccus marginatus*), spiralling whitefly (*Aleurodicus dispersus*), brinjal shoot and fruit borer (*Leucinodes orbonalis*), Bactrocera fruit flies and phytophagous mites. Surveillance, biological control, sanitation, resistant material where available, traps and selective pesticides are important components.

10.4. Invasive pests. Climate suitability and movement of plant material can jointly increase the risk of establishment of invasive pests. Fall armyworm (*Spodoptera frugiperda*) illustrates the need for coordinated surveillance, early detection, farmer awareness, biological control, resistant cultivars where available and judicious chemical intervention. Phytosanitary systems and regional cooperation remain essential.

11. Conceptual Framework for Climate-Resilient IPM

A practical framework can be organized as an adaptive cycle: (i) climate intelligence through weather monitoring and risk assessment; (ii) pest surveillance using scouting, traps, remote sensing and diagnostics; (iii) evaluation of pest abundance, crop vulnerability, natural enemy activity and economic thresholds; (iv) selection of integrated interventions; and (v) assessment of pest suppression, yield, pesticide use, environmental effects and profitability. Findings from the evaluation should feed back into subsequent decisions.

The framework links climate information with field observations and integrated tactics. It emphasizes that climate-resilient IPM is dynamic: recommendations must be refined as climatic conditions, pest behaviour and field outcomes change.

12. Challenges and Research Gaps

12.1. Limited long-term datasets. Many pest forecasts rely on short observation periods. Long-term records are needed to identify changes in phenology, distribution, abundance and outbreak frequency.

12.2. Incomplete understanding of multitrophic responses. Studies often focus on direct temperature effects on pests, while combined responses of host plants, parasitoids, predators and pathogens remain less well understood.

12.3. Regional variability. Recommendations from one agroclimatic zone may not transfer directly to another. Local validation and model calibration are necessary.

12.4. Access and adoption. Smallholder farmers may face barriers involving digital literacy, connectivity, technology cost and access to dependable advice.

12.5. Institutional and economic constraints. Wider adoption requires extension support, reliable access to quality biological-control agents, farmer coordination and economic assessment.

Research priorities include long-term pest monitoring; region-specific forecasting; climate-adapted biological control; studies of plant–pest–natural enemy interactions under heat and drought; integration of AI, remote sensing and field scouting; resistant cultivars; economic evaluation; and participatory research.

13. Future Perspectives

Climate-resilient IPM will depend on closer integration of ecological knowledge, climate science, agricultural technology and farmer participation. A key priority is to anticipate climatic risks rather than respond only after outbreaks. Climate-informed forecasting, automated surveillance and decision-support tools can improve intervention timing and reduce avoidable pesticide use.

Biological control and ecological engineering will remain central, but their reliability under changing conditions requires a stronger understanding of thermal tolerance, ecological adaptability and interactions with target pests. Traditional agricultural knowledge can be combined with modern tools to improve local relevance. Farmer Field Schools, participatory surveillance and community-based programmes can strengthen decision-making and adoption.

Future assessments should consider more than pest suppression alone. Pesticide use, natural-enemy abundance, crop yield, profitability, biodiversity and ecosystem services are useful indicators for evaluating whether a system is genuinely resilient and sustainable.

14. Conclusion

Climate change is reshaping agricultural pest dynamics by influencing insect development, reproduction, distribution, host-plant susceptibility and natural-enemy performance. These shifts challenge conventional pest management and strengthen the case for adaptive, predictive and ecologically sound crop protection.

Climate-resilient IPM provides a framework for combining preventive cultural practices, host-plant resistance, biological control, ecological engineering, precision tools and need-based chemical interventions. Integrating climate information into surveillance and decision-making can improve the timing and efficiency of management. Conservation of natural enemies, crop diversification and landscape-level management can further strengthen agroecosystem resilience.

For Indian agriculture, climate-resilient IPM offers opportunities to reduce dependence on pesticides and stabilize crop protection under climatic variability. Implementation will require region-specific research, long-term monitoring, accessible technologies, effective extension and institutional coordination. Ultimately, climate-resilient IPM is a dynamic approach that brings ecological regulation, scientific innovation and farmer participation together to support sustainable crop protection, biodiversity and food security.

Table 1. Climate-related challenges and *Corresponding IPM responses

Climate-related challenge	Potential consequence	IPM response
Rising temperature	Accelerated pest development	Temperature-based forecasting
Irregular rainfall	Changes in pest survival and crop susceptibility	Weather-informed surveillance
Drought stress	Altered host quality and pest feeding	Crop stress management and resistant cultivars
Heatwaves	Reduced natural-enemy activity	Conserve and assess adapted natural enemies
Range expansion	Emerging or invasive pests	Biosecurity and early detection
Extreme weather	Disrupted field operations	Adaptive, need-based interventions
Elevated CO_2	Changes in plant nutritional quality	Monitor and reassess thresholds

Table 2. Technologies and their applications in climate-resilient IPM

Technology	Major application	Potential benefit
GIS and remote sensing	Crop stress and pest-risk mapping	Improved spatial surveillance
AI image analysis	Automated insect identification	Faster pest diagnosis
IoT smart traps	Continuous pest monitoring	Timely detection
Weather-based models	Pest development forecasting	Improved intervention timing
Mobile applications	Pest identification and advisories	Improved farmer access
Precision spraying	Targeted pesticide application	Reduced pesticide wastage
Molecular diagnostics	Identification of invasive pests	Improved biosecurity

Figure 1. Conceptual framework for climate-resilient IPM

Climate change and climatic variability → Climate intelligence → Pest surveillance and early warning → Pest risk assessment and economic thresholds → Integrated interventions (cultural and preventive management; biological control and ecological engineering; precision and need-based chemical management) → Pest suppression and agroecosystem resilience → Crop productivity, biodiversity and sustainability → Monitoring, evaluation and adaptive feedback to climate intelligence.

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